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UNIFORMITY OF METHODS IN TESTING WATER METERS.

BY

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[Read Sept. 11th, 1895.]

The increasing use of water-meters, and the rapidly growing sentiment in favor of their application, is leading to the more general testing of meters by water works officials; as also to more exacting requirements respecting their performance, and especially is this the case regarding the low-rate registration of the smaller sizes of meters used in domestic service. This observation at once leads to the query: Is it not time that more uniform methods of testing be adopted by the purchasers of meters; especially in the smaller calibres for domestic use?

It is believed that the question answers itself affirmatively; but among the reasons leading to this conclusion it may not be amiss to mention that, as between the purchaser and the manufacturer, the advantage would be mutual; the single illustration sufficing that the conditions are here almost identical with that of uniform standards in pipe-threads and flanges.

The corollary, then, is query number two. In what particulars of meter-testing should uniformity of methods be attempted?

Here, undoubtedly, there is room for many opinions, and it is hoped that the discussion evolved may lead to a codification of present rules and practices. The writer selects the following features, which to him appear as most deserving of consideration and adoption, namely: first, should not the rating of meters, especially in low flow tests, be by timing the deliveries of definite quantities, rather than by designating the diameter of jets; second, what shall be the limit of the minimum rate; third, what shall be the limit of the maximum rate; fourth, should tests be referred to the meter or the tank; fifth, should the error be indicated in pounds or percentage.

LOW FLOWS SHOULD BE DESIGNATED BY TIME-RATING.

As to the first, namely: the method of rating at low flows, the writer is strongly of the opinion that the time-rate should be adopted, as being correct in theory and thoroughly demonstrated by long practice, especially so in Europe. The amount of uncertainty regarding this subject can probably be best attested by the vendors of water-meters, to whom the most widespread experiences converge. Thus, the inquiry may be from one, "how accurate will your meter work," with no mention of pressure, conditions, range or rate; from another, "meter must test down to a fine stream," and when this is defined you may receive the specification, "on a stream as small as a darning needle," the pressure being, say, 30 lbs.; or from another, "on a stream about as big as a pipestem," and the pressure in the latter case may be 100 lbs. Then, too, where the practice has advanced to the employment of perforated diaphragms, it is rather the exception than the rule for purchasers to make note as to the form of the perforation or the pressure behind it. And, moreover, as between the aggregation of thin brass, punched; copper pennies, drilled; lead diaphragms pierced by an awl, and the eminent expert who laid the fault of a certain test to the fact that a perforation alleged to be $\frac{1}{32}$ inch dia., was found to be 0.0075 inch too large, there might yet be added such cases as where the decimal 0.0625 inch was read $\frac{1}{90}$ inch, with results as entirely satisfactory to the manufacturer, as in the instance of a certain wasteful child of Neptune, who said, "Fix my meters to measure by the barrel, when I want to sell water by the drop I'll order a Homeopathic vial and a quill!"

Now, let it be said, that in testing a meter at low flows, the only point desired to be known is, what quantity in pounds, gallons or cubic feet is passing in a minute or an hour; the sensibility of the meter is alone established by this; if one meter, to operate accurately, requires a draught of 2 cubic feet uniformly drawn in one hour; and another meter operates with equal accuracy upon a draught of 1 cubic foot in the same time, then the latter has twice the sensibility of the former. The only function, then, of a throttling diaphragm is to determine the rate of flow, and the only method of ascertaining this is to carefully rate the perforation by measuring its discharge under a definite pressure for a definite period of time. If time-honored truths will bear repeating, then so will hydraulic principles; which alone is the excuse for here presenting a few illustrations, with the view of impressing upon the memory the importance of following the procedure just recommended.

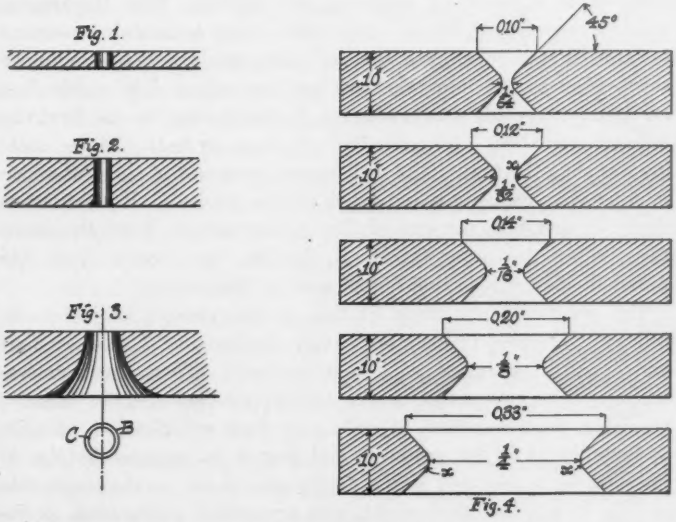


Fig. 4.

Thus, in Fig. 1 is represented, to a large scale, a diaphragm, the original of which is $\frac{1}{32}$ inch thick; the perforation being precisely $\frac{1}{32}$ inch diameter, with the edges knife-sharp. The delivery of this orifice under a pressure of 50 lbs. to the square inch is approximately 1 cubic foot an hour. In Fig. 2 a diaphragm is represented

to the same scale as Fig. 1, the original of which is $\frac{3}{32}$ inch thick, having precisely the same diameter of orifice and the same knife-sharp edge on the upper side, but with the lower edge very slightly rounded by lightly scraping the edge with a sharp knife. The delivery of this diaphragm, under the same pressure as the former, with the upper sharp edge to the flow, is nearly 1.12 cubic feet an hour. Hence the difference in thickness alone gives the thin diaphragm, at the pressure named, 12 per cent. *less* delivering capacity than the thicker one. Again, with this diaphragm reversed, the slightly rounded edge to the flow, the delivery is nearly 1.50 cubic feet an hour, or 33 per cent. greater delivering capacity than from the sharp edge. These are to show how apparently trivial differences may greatly affect the comparison of results. Again, referring to Fig. 3, a diaphragm is represented in the original, of which the perforation is precisely $\frac{1}{16}$ inch diameter, the thickness $\frac{1}{8}$ inch, one edge knife-sharp and the other very nicely rounded to a curve of about $\frac{1}{8}$ inch radius. This diaphragm, under a pressure of 50 lbs., each side being separately presented towards the pressure, gave the following result: With the upper sharp edge to the inlet, the delivery was about 5.30 cubic feet an hour; reversed, with the lower rounded edge to the flow, the delivery was about 7.10 cubic feet an hour, or nearly 34 per cent. greater than the first. The well-known reason for this difference in delivering capacity is indicated in the circles C, B; the inner circle, C, denoting the area of the contracted jet, from the sharp edge, while the outer circle, B, denotes the stream from the rounded side equal to that of the area of the orifice.

The practical application of this to the present subject is as follows: Suppose two meters equally accurate at 7 feet an hour and equally inaccurate at 5 feet an hour. Then, furthermore, suppose that two water works are supplied with these meters, requiring them accurate, according to their specification, on a jet $\frac{1}{16}$ inch dia. at 50 lbs. pressure, and that it so happens that one of these works is provided with a diaphragm, sharp, as the upper side of Fig. 3, and the other works, with a rounded perforation, as the low side of said figure. Obviously, the works using the sharp-edged diaphragm will find the meter defective, whilst the other will be accepted as correct. Evidently, had these meters been ordered to be correct at a minimum rate of 5 cubic feet an hour, and had

then been tested respectively under conditions to obtain this rate of flow, each purchaser would have been equally suited, and the cup of human happiness would have been nearer to the full.

As a means tending to reach the result here aimed at, it is suggested that a standard form of perforation be adopted in the diaphragms used in testing water-meters, and it is believed that the forms shown in Fig. 4, when taken with the simple method of their construction, would come well within the practical requirements of such service. In the several parts of the aforesaid figure which are drawn to a considerably enlarged scale, five diaphragms are shown, the diameters, at the throat-sections of the perforations, being those already most generally employed, namely: $\frac{1}{64}$, $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$ and $\frac{1}{4}$ inch respectively.

To most conveniently accomplish the end here sought, it is essential that the several diaphragms of a series shall be of uniform thickness, and No. 10 American gauge, or approximately 0.10 inch, has been selected; the metal to be of hard rolled brass. The production of any one of the perforations is as follows: first pierce with a drill one size smaller than the desired gauge; second, with an accurately ground counter-bore, of 45° angle, counter-sink each side of the metal disk until the large diameter on the face, as noted in the drawing, shall be reached; third, the throat is then to be brought to exact diameter by reamer and round brooch, and, finally, the sharp knife-edge portions at the intersections of the throat with the cones, as at X, are to be lightly polished out by using a pointed stick with pumice stone. The object of sinking the counter-bore to produce a definite diameter at the face, is to establish the depth of the cone; and these face dimensions are such as to produce a uniform thickness and contour at the throat in all of the sizes. The advantages of making both sides alike, and of counter-boring, are that either side may be presented towards the inlet, and that the throat is protected from injury.

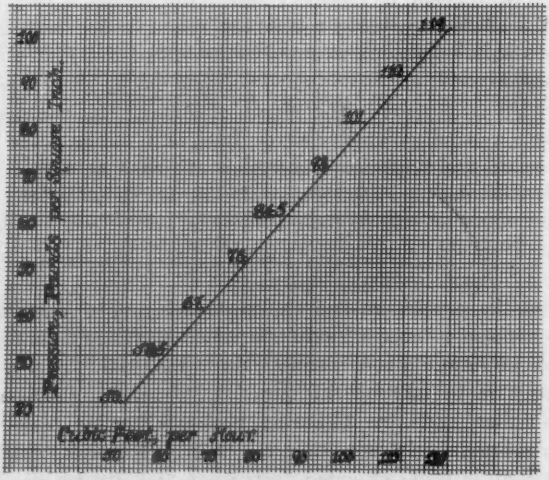
If both the purchasers and the manufacturers of water-meters would conclude to accept even this mild departure from existing practice, there would be a distinct gain to the good. And to those who may care to take up this practice, of referring comparative tests to a time basis, the following time-rate testing table is presented, approximately indicating the hourly deliveries which may be expected, in terms of cubic feet, when the diaphragms herein

described are employed, and when the dynamic, or "running," pressure named is maintained at the diaphragm.

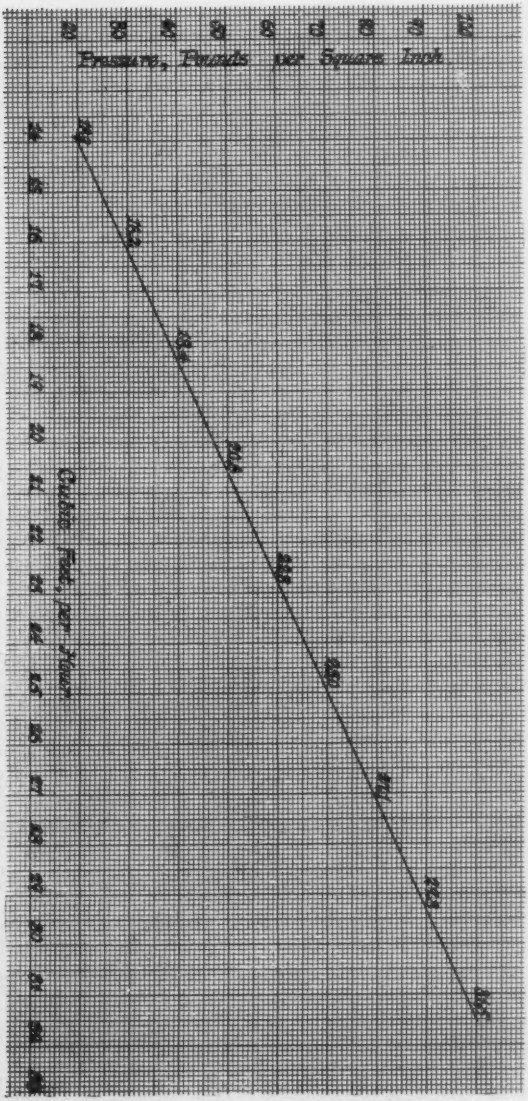
WATER METER BENCH-TESTING TABLE, GIVING APPROXIMATE RATES OF DELIVERY IN CUBIC FEET PER HOUR OF NEAREST EVEN QUANTITY THROUGH PERFORATIONS FORMED AS SHOWN IN FIGURE 4.

Pressure.	Diameter. Inches.				
Pounds.	1-64	1-32	1-16	⅛	¼
20		0.75	4.00	14	50
30				16	58
40		1.00	5.25	18	67
50	0.50			20	76
60		1.25	6.50	23	84
70				25	93
80			7.50	27	101
90				29	110
100	0.75	1.50	8.50	31	119

NOTE.—It was originally contemplated to prepare this table to show approximately exact deliveries for pressure increments of 5 lbs.; but after having prepared such a tabulation, it appeared to the writer, that a wider range in pressures quantities averaged to even amounts would inadequately meet the requirements of regular service. Moreover, it is thought that the table, because of the increased simplicity and brevity, will be more likely to be utilized by practical men. Where deliveries at intermediate pressures are desired, they may be ascertained from the following diagrams:



APPROXIMATE DELIVERY THROUGH ¼" ORIFICE FORMED AS SHOWN IN FIG. 4.



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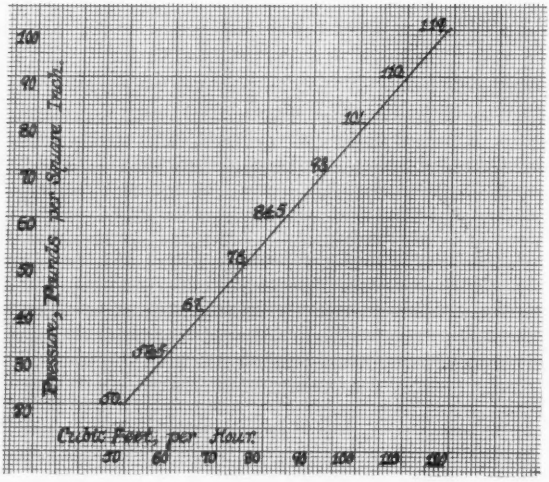
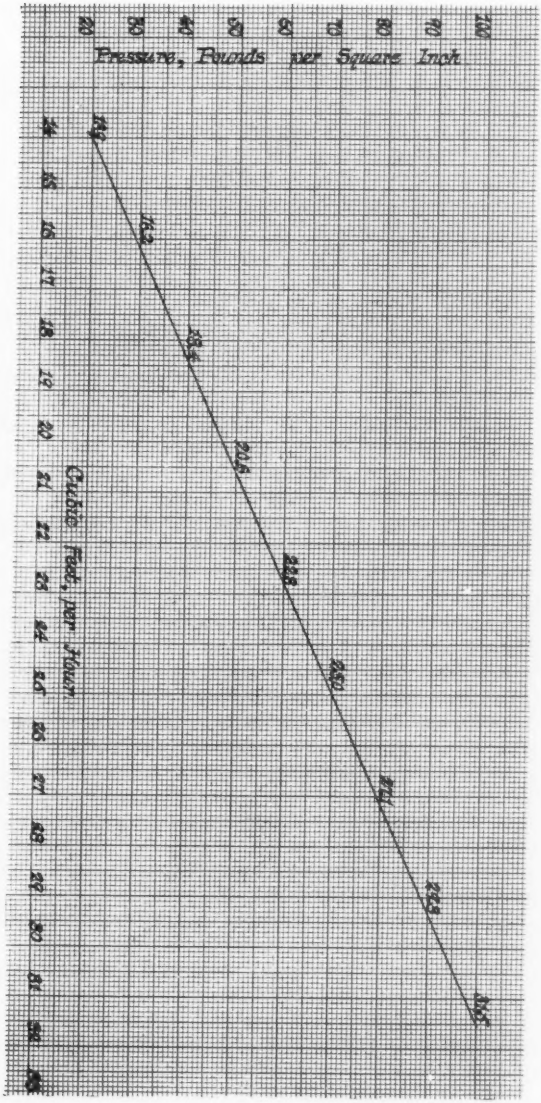
WATER METER BENCH-TESTING TABLE, GIVING APPROXIMATE RATES OF DELIVERY IN CUBIC FEET PER HOUR OF NEAREST EVEN QUANTITY THROUGH PERFORATIONS FORMED AS SHOWN IN FIGURE 4.

Pressure.	Diameter. Inches.				
Pounds.	1-64	1-32	1-16	3/8	1/4
20		0.75	4.00	14	50
30				16	58
40		1.00	5.25	18	67
50	0.50			20	76
60		1.25	6.50	23	84
70				25	93
80			7.50	27	101
90				29	110
100	0.75	1.50	8.50	31	119

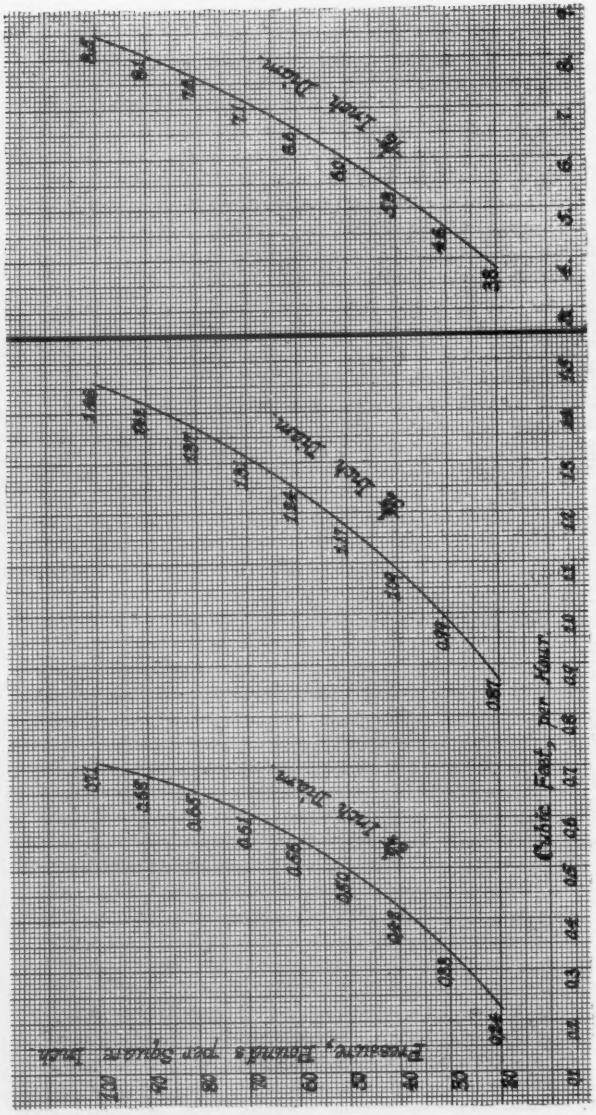
NOTE.—It was originally contemplated to prepare this table to show approximately exact deliveries for pressure increments of 5 lbs.; but after having prepared such a tabulation, it appeared to the writer, that a wider range in pressures quantities averaged to even amounts would inadequately meet the requirements of regular service. Moreover, it is thought that the table, because of the increased simplicity and brevity, will be more likely to be utilized by practical men. Where deliveries at intermediate pressures are desired, they may be ascertained from the following diagrams:



APPROXIMATE DELIVERY THROUGH 1/4" ORIFICE FORMED AS SHOWN IN FIG. 4.



APPROXIMATE DELIVERY THROUGH $\frac{1}{8}$" ORIFICE FORMED AS SHOWN IN FIG. 4.



Approximate Deliveries Through $\frac{1}{4}$", $\frac{3}{8}$" and $\frac{1}{2}$" Orifices Formed as Shown in Fig. 4.

In carrying out these determinations of jet deliveries through the definite forms of perforation illustrated in Fig. 4, the water was weighed. A pair of Aschcroft test-gauges were used, these being specially compared and furnished under order to be graduated from a mercury column. The pressures were obtained by a Worthington pump and a Fisher regulator, both of which were specially overhauled and refitted for the purpose of obtaining this data. The pressure, as indicated by the gauge, was maintained with satisfactory steadiness. Any refinement of scientific accuracy, however, "the triumph of the last place of decimals," is expressly disclaimed, but judging from the uniformity of indications under repeated experiments, it is believed that the results from which this table was prepared are well within the practical requirements of the intended service. (In this connection, see foot-note on table, page 82.)

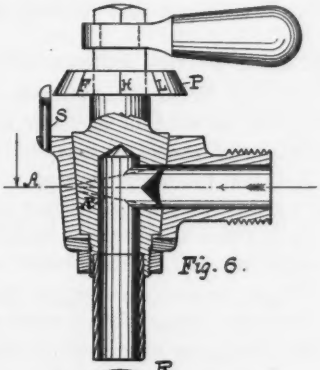
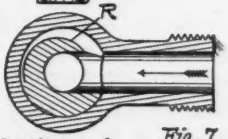


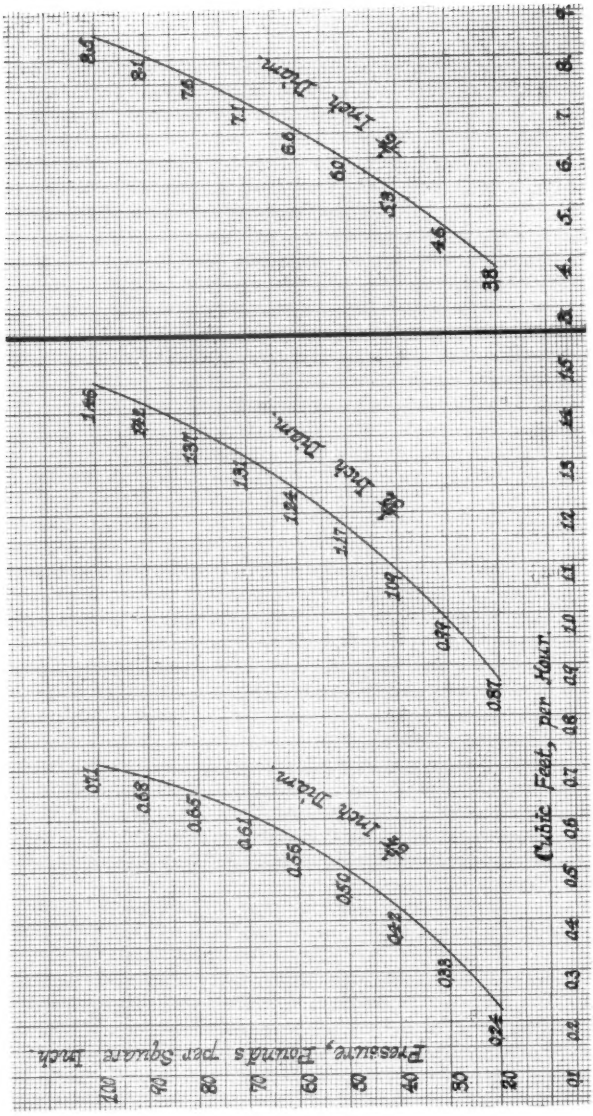
Fig. 6.



Section on A

Fig. 7.

In Figs. 6 and 7 two sectional details are shown of a graduated valve for testing water-meters by time-rating, as used by the writer's company, which so far has proven quite satisfactory in practice. This device consists of a simple plug-valve adapted to receive the flow at the side and discharge from a tube inserted in



Approximate Deliveries Through $\frac{1}{64}$", $\frac{1}{32}$" and $\frac{1}{16}$" Orifices Formed as Shown in Fig. 4.

In carrying out these determinations of jet deliveries through the definite forms of perforation illustrated in Fig. 4, the water was weighed. A pair of Ascheroft test-gauges were used, these being specially compared and furnished under order to be graduated from a mercury column. The pressures were obtained by a Worthington pump and a Fisher regulator, both of which were specially overhauled and refitted for the purpose of obtaining this data. The pressure, as indicated by the gauge, was maintained with satisfactory steadiness. Any refinement of scientific accuracy, however, "the triumph of the last place of decimals," is expressly disclaimed, but judging from the uniformity of indications under repeated experiments, it is believed that the results from which this table was prepared are well within the practical requirements of the intended service. (In this connection, see foot-note on table, page 82.)

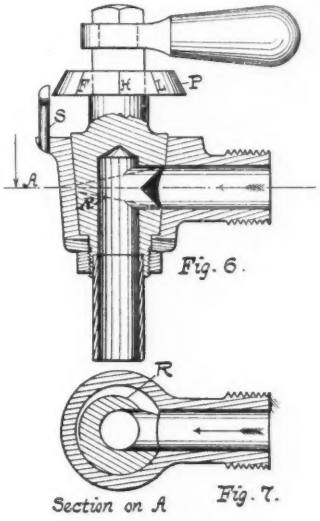


Fig. 6.

Section on A Fig. 7.

In Figs. 6 and 7 two sectional details are shown of a graduated valve for testing water-meters by time-rating, as used by the writer's company, which so far has proven quite satisfactory in practice. This device consists of a simple plug-valve adapted to receive the flow at the side and discharge from a tube inserted in

the end of the plug; about half the circumference of the side of the plug being recessed to the form of a V, gradually diminishing both in depth and width from the main inlet until vanishing in the surface, as denoted by the letter R, in the drawings. Applied to the upper extension of the plug is a dial-plate, P, and inserted into the face of the casing is a sight-pin, S. Obviously, by simply turning the plug so that different portions of the circular V-groove is presented to the inlet, the area of discharge may be very uniformly increased or decreased between the entire range of the scale. Then, by timing the delivery, any desired series or combination of tests may be made. In our practice the letter F is stamped on the graduate to indicate full flow, H for half; L for low and S for sensibility, these, under 60 lbs. pressure, giving approximate rates of 90, 40, 15 and 1.5 cubic feet an hour. Where many meters are to be tested at different rates, this device effects a considerable saving in time over that required in the changing of diaphragms.

THE LIMIT OF THE MINIMUM RATE.

As to the second query. What minimum rate should be insisted upon in water-meters, to be used in domestic service, the writer holds the opinion that this should be adapted to the conditions of the service. But the following general recommendation is ventured: When the water is reasonably pure and free from grit, it is believed to be well within the power of manufacturers to regularly supply the smaller sizes of positive rotary and piston meters to indicate within 3 per cent. of accuracy at the rate of 1 cubic foot uniformly drawn in one hour. And a meter which will do this may generally be depended upon to indicate, though not necessarily with much accuracy, down to from $\frac{3}{4}$ to $\frac{1}{2}$ a cubic foot an hour. But the insistence upon such a degree of sensibility, except only where the water is free from grit, may invariably be taken as indicative of anything except good engineering sense. In this connection, however, it is not to be overlooked that the employment of meters and the reduction of waste tends, to the betterment of a water supply.

AS TO THE MAXIMUM RATE.

And now as to the third query of the opening. What should be the limit in testing a meter to maximum operation? The answer to this, if taken from general practice, is easy, namely: all that can

be blown through. The writer has known of many cases where the only tests for accuracy in meters of the ⅝-inch size were at the rate of from 3 to 4 cubic feet a minute, that is from 300 to 400 per cent. in excess of usual practical requirements. In a test to demonstrate the durability, or the extreme power and capacity of a meter, such a trial may be eminently proper; but there appears to be but little warrant for such a practice as a check for accuracy. However, opinions differ widely on this point, notwithstanding that there appears to be an entirely satisfactory basis for such tests, even though empirical, namely: the highest maximum delivery likely to be drawn through regular service pipe. A bench test to check performance under such conditions is obviously of value; from this down to the minimum rate is the field of the performance of the meter. It would seem that the extreme velocity in the commercial sizes of ½, ¾ and 1 inch service pipe of, say, 15 lineal feet a second, is about as high as good practice would warrant. As a matter of fact, such a velocity is not common, but even this extreme rate would only discharge nearly 1.8, 2.8 and 4.8 cubic feet respectively; hence a bench-test for accuracy at maximum rate probably need rarely exceed, say, 2 cubic feet a minute for a ½ or ⅝-inch meter; 3.5 feet for the ¾-inch meter, and 6 feet for the 1 inch.

IN LOW RATE FLOWS SHOULD THE METER BE THROTTLED AT THE INLET OR THE OUTLET.

The inquiry is occasionally made if, in testing a meter under low flows, it makes any difference in the results as to whether the meter be throttled at the inlet or the outlet thereof. Generally speaking, it is more favorable to the meter to throttle at the inlet, leaving the outlet fully open, as it is thus relieved of all strain except that of the back-pressure of the outlet pipe. If meter-devices were in theoretically perfect equilibrium, under pressure, there would be no difference; but, within the knowledge of the writer, there is no such mechanism. Consequently, if it were desired to obtain registration at the very lowest rates of flow, it would be advantageous, if the conditions would permit, to throttle at the inlet, leaving the outlet free; but it is essential in such cases that the pipe leading from the outlet side of the meter shall be so arranged as to keep the meter full of water, that is under a minimum of

back-pressure. This admonition is offered for the reason that the writer has heard of a number of cases in which this precaution was neglected; in consequence of which the meters were operated with their upper chambers empty. And although in the instance of models adapted to kindergarten exhibits, this vacuous condition has been advantageously utilized (as even betimes by the conscientious meter-maker), it is not to be recommended for regular practice. But in all regular bench-tests the meter should be throttled at the outlet when tried for sensibility; as this is the condition under which the device must regularly operate.

A FEW PRIMARY RULES TO BE OBSERVED IN BENCH-TESTING.

Water should be turned on to an empty meter slowly, until completely filled.

It is preferable to run a small quantity through a meter before starting a test.

In all meters it is desirable to eject the air before testing. The most ready and efficient means to this end, when vent screws are not provided, is to turn the meter over a few times, when connected for the test, on its side, or upside down, in which position it should be operated to drive out the air displaced by the change of position. This precaution is usually not worth observing when setting the meter in regular circuit; as the entrained air will gradually be absorbed and ejected.

In testing by weight, when using a tank mounted upon a platform scale, if especially accurate results are desired, it is well to read the scale-lever as it swings to some arbitrarily fixed mark near its end; the reason for this being that the majority of such scales are "logy" when loaded, and can often be read from one to three pounds in error.

In testing by tanks, provided with glass tubes, there is a source of error due to capillarity; the extent of which varies somewhat with the condition of the atmosphere and the observer and the degree of cleanliness of the inner surface of the tube. Thus with a clean surface and pure water, the end-surface of the column will be concave, due to the attraction of the glass; whereas, if the surface of the glass is greasy, this will act to repel the water and the end-surface of the column will be convex. On the whole, it is well to

swab out such tubes occasionally, and a little alcohol on the swab will not hurt the job. In view of these conditions, it is generally believed to be the most uniformly reliable procedure to read the height of the column from the center thereof, be it concave or convex. And this is an argument in favor of glass tubes of large diameter.

Where the most exacting results are desired from a meter in low flow performance, the pressure should be maintained as nearly uniform as possible. If the pressure varies considerably, this may result either favorable or unfavorable, either to the maker or the purchaser. The reason for this is that a pulsating pressure, during sensibility flows, may produce different effects upon different meters.

When using the $\frac{1}{64}$ inch or the $\frac{1}{32}$ inch diaphragms, especially if the test is to be of long duration, it is well to insert a piece of sponge to prevent particles of grit from closing the perforation.

In all positive meters having hard rubber displacing members, more accurate results may be expected, at low rate performance, when the water used for the test is rather tepid than cold; the reason for this being that the normal co-efficient of expansion and contraction of hard rubber is greater than that of brass or composition. This fact is taken into consideration, occasionally, in the construction of meters. It is for this reason that a meter will often fail to operate freely by blowing when taken from a shelf in a warm room, but will be all right when cooled in water.

A meter which operates correctly at the higher and lower rates of flow and fails on the sensibility trial, may often be corrected by simply reversing the meter and running it backward for a few minutes; as, if the cause of the difficulty was a slight foreign obstruction, this treatment will often remove it.

In a water meter, to ascertain its obstruction to the delivery, relative to the service pipe, proceed as follows: First, insert a piece of regular service pipe of the same nominal size and the same length as the meter, placing it in the same position and using the same couplings and packing-washers as are used when testing the meter. Second, apply a diaphragm to the outlet, as in regular testing, whose diameter is somewhat less than that of the bore of the spuds of the meter. Third, then make a number of runs, each of exactly the same amount, and carefully record the time of each

run. Thus, if you have made four runs of 10 cubic feet each and the time of each flow is 2½ minutes, you will have an aggregate of 40 feet divided by 10 minutes equalling 4 cubic feet a minute, the capacity of the pipe. Now, insert the meter (or the several meters, successively, if the test is to be comparative of kinds) in place of the piece of pipe, again being careful to use the same connections, and packing-washers as in the instance of the pipe. Then proceed as before, and run the same quantity for the same number of tests and carefully record the time required for the delivery of each. Should you have an aggregate of 40 feet delivered in 12 minutes, in the case of one meter, then its relation to the pipe would be 10 divided by 12, that is the meter would have a capacity equal to 83.3 per cent. of that of the pipe. If another meter should require 13 minutes, its capacity relative to the pipe would be 76.9 per cent. and the first meter would have 8.3 per cent. greater capacity than that of the second. ($\overline{83.3-76.9}\div 76.9=8.3$ per cent.)

In bench-tests, the usual trial runs are as follows: One, two, five and ten cubic feet, the correct weight equalling, respectively, 62½, 125, 312½ and 625 lbs. Sensibility tests, because of the time required, are frequently made by tenths of a foot, each tenth being equal to 6¼ lbs., or approximately 3 quarts. In connection with the foregoing, the following percentage table may be of service:

PERCENTAGE TABLE FOR BENCH-TESTING OF WATER METERS.

1 Cubic Foot=62.5 lbs.

Actual Indication of Meter in percent.	Error in percent.	Cubic Feet Indicated by Meter to Pounds of Water Found in Tank.			
		1.	2.	5.	10.
	Over				
104.1	4.1	60.0	120.0	300.0	600.0
103.3	3.3	60.5	121.0	302.5	605.0
102.4	2·4	61.0	122.0	305.0	610.0
101.6	1.6	61.5	123.0	307.5	615.0
100.8	0.8	62.0	124.0	310.0	620.0
100.0	0.0	62.5	125.0	312·5	625.0
	Under				
99.2	0.8	63.0	126.0	315.0	630.0
98.4	1.6	63.5	127.0	317.5	635.0
97.6	2.4	64 0	128.0	320.0	640 0
96.9	3.1	64.5	129.0	322.5	645 0
96.1	3.9	65.0	130.0	325.0	650.0

PERCENTAGE AND TIME-RATE TABLE FOR FRACTIONAL SENSIBILITY OR "LEAKAGE" TESTS.

Actual Indication of Meter in Percent.	Error in Percent.	ONE TENTH *Cubic Foot* Indicated by Meter to Pounds of Water in Tank.
	Over	
108.6	8.6	5.75
104.1	4.1	6.00
100.0	0.0	6.25
	Under	
96.1	3.9	6.50
92.5	7.5	6.75
89.2	10.8	7.00
86.2	13.8	7.25
83.3	16.7	7.50
80.6	19.4	7.75
78.1	21.9	8.00
75.7	24.3	8.25
73.5	26.5	8.50
71.4	28.6	8.75
69.4	30.6	9.00
67.5	32.5	9.25
65.6	34.4	9.50
64.1	35.9	9.75
62.5	37.5	10.00

One-tenth Indication in 3 minutes equals a rate of 2 cubic feet an hour; in 3m. 30s. = 1.7; in 4m. = 1.5; in 4m. 30s. = 1.3; in 5m. = 1.2; in 5m. 30s. = 1.1; in 6m. = 1.; in 6m. 30s. = 0.92; in 7m. = 0.85; in 8 m. = 0.75; in 9m. = 0.66; in 10m. = 0.60; in 11m. = 0.55; and in 12m. = 0.50.

IN BENCH-TESTING, WHICH SHOULD BE THE STANDARD OF REFERENCE, THE METER OR THE QUANTITY FOUND IN THE TANK?

Theoretically, there is hardly any question but that in running a trial quantity into a gauged receptacle, the meter ought to be stopped when the amount intended to be indicated by the meter is in fact shown by the scale, or tank; but practically this is not as convenient, nor can as accurate answers be obtained, ordinarily, as when the quantity intended to be run is *indicated*, whether correctly or incorrectly, by the register of the meter. The reason for this view of the subject is that commercial water-meters, even in the smaller sizes, are not adapted to be read less than 0.10 cubic foot; whereas any degree of refinement may be obtained in the scale. Hence, in the writer's opinion, all meter tests, especially when small quantities are run, should be by the meter. The importance of this in practice may be best understood by presenting a brief illustration.

Suppose that 10 cubic feet, regarded as 625 pounds, to have been run in a tank; but that the hand of the register is "shy" of the naught-mark; the actual extent of the error can only be judged; to accurately ascertain it, the meter must be operated until the hand reaches the dial-mark, and yet, by doing this, the exact reference quantity in the tank has been increased.

From these conditions and circumstances frequent misunderstandings have arisen; thus, as to whether when a meter was reported as "under" or "over," it in fact registered less than the tank or the tank more than the meter. All such misunderstandings would be avoided by concurrence in the following procedure and interpretation: First, that the meter be run until the intended trial quantity is indicated by the register. Second, that when the quantity found in the tank is *more* than the amount indicated by the meter, it shall then be understood that the meter under-registers, or is "under." Third, that when the quantity is found in the tank is *less* than that indicated by the meter, then the meter over-registers, or is "over."

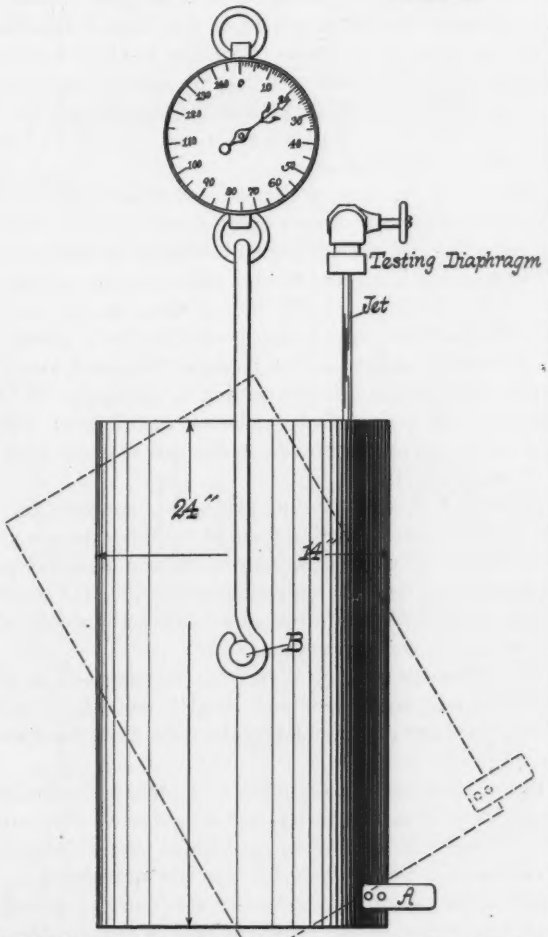
SHOULD THE ERROR OF METERS BE RECORDED IN TERMS OF POUNDS OR PERCENTAGE?

It is believed that it would be preferable if the indication of meters were uniformly denoted, on all test-cards and records, in terms of percentage of the quantity indicated. This is now done in but comparatively few cases, the usual practice being to record the error in pounds, plus or minus, or in the percentage of error, plus or minus. These three methods of recording may be quickly brought clearly to mind by assuming a meter as indicating 10 cubic feet but with 635 pounds found in the tank. This can be recorded $635-625=10$ pounds "under;" or $10\div635=1.6$ per cent minus; or $625\div635.0=98.4$ per cent., that is the exact quantity registered by the meter. To the writer at least, in a column of tests recorded in the latter way, it is more satisfying to the mind than in terms of pounds or differences.

APPARATUS FOR TESTING WATER METERS.

In testing water-meters there are two reliable systems available, namely: by weighing the trial quantity, or by the use of a calibrated tank. In European practice, graduated tanks are largely,

Plate 8.



Galvanized Iron Can Suspended on Spring Scale. Maximum Testing Capacity, 2 Cubic Feet or 15 U.S. Gallons. To Empty: swing by Handle A on Trunions B

John Thomson

almost entirely, employed; in America, measurement by weight is most commonly in vogue. It is now believed by the writer that the graduated tank is the better system, in that there is less liability to error in observation; variations of volume due to the difference of temperature is obviated, and tests may be made in less time. There is no question, however, but that the weighing system is the cheaper to install, as with but a platform scale and an old oil barrel first rate results may be obtained.

In plate 8 is shown one of the handiest, least expensive and yet accurate testing systems, known to the writer, consisting of a simple galvanized iron can, swung upon an iron axis, from which, like the handle of a pail, it is suspended from a common spring balance scale having a total indication of 150 lbs. A tank, or can, 14-inch dia. by 24 inches long will afford ample capacity for a test of 2 cubic feet. First-class results can be obtained from such an apparatus, especially where "fine-haired" testing is required. Thus within the range of the scale, 1 foot can be run at full flow; half a foot at half rate; two or three-tenths at low and as many more for the limit of sensibility.

In plate 9 is indicated a testing-plant, in schematic detail, which may be of service as a starting thought to those who may regard the installation of a reliable, convenient and durable system as worth the while. Such an apparatus, adapted to the conditions of the place, would be comparatively inexpensive and would be conducive to uniformly accurate results.

In the calibration of such a tank as is indicated in the plate, probably the most convenient and reliable method, is by carefully weighing the water and graduating the scale from the water in the tube.

In the writer's practice a number of meters are tested in series; this being done to make the time and save water. But, ordinarily, this would hardly be worth the extra cost of special fixtures. Moreover, this method involves special care and aptitude on the part of the operator to insure the ejection of air from the meters and an accurate comparison of the several indices of the registers.

While much more might be said and many details be here added, it is believed that that which might come from the practice and experience of others would be of much greater value; hence, the subject is now in your hands with this final observation: Your successful

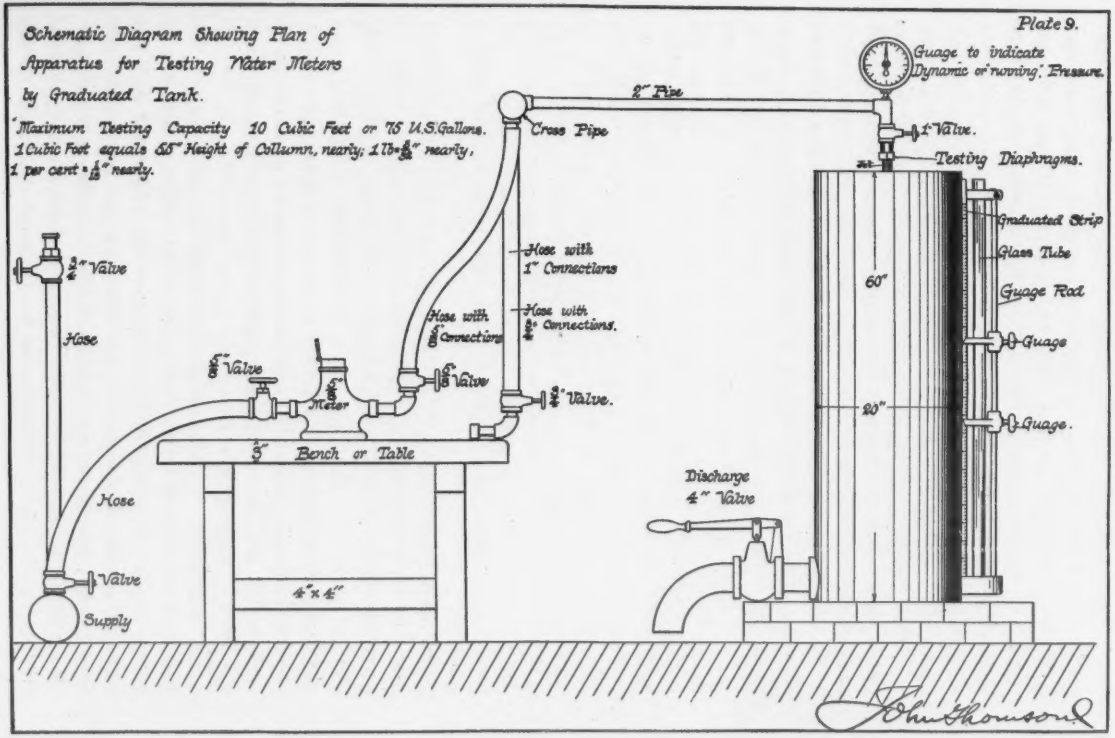


Plate 9.
Schematic Diagram Showing Plan of Apparatus for Testing Water Meters by Graduated Tank.
Maximum Testing Capacity 10 Cubic Feet or 75 U.S. Gallons.
1 Cubic Foot equals 65" Height of Column, nearly; 1 lb = 5/8" nearly,
1 per cent = 1/12" nearly.
Guage to indicate Dynamic or "running" Pressure.
2" Pipe
Cross Pipe
1" Valve.
Testing Diaphragms.
Graduated Strip
Glass Tube
Guage Rod
Guage
Guage.
60"
20"
Hose with 1" Connections
Hose with 5/8" Connections.
Hose with 3/4" Connections.
3/4" Valve
Hose
5/8" Valve
Meter
5/8" Valve
3/4" Valve.
Bench or Table
Hose
Valve
Supply
4" x 4"
Discharge 4" Valve
John Thomson

meter-tester must be a man of parts; he should have many of the attributes of the successful fisherman, as skill, judgment and patience; and when to these are added plenty of bait and good tackle so much the more certain will be the results. And so it is in the bench-testing of water-meters.

DISCUSSION.

THE PRESIDENT. Gentlemen, you have heard this very interesting paper on this exceedingly interesting subject, and it should have considerable discussion.

MR. HASKELL. I did not hear Mr. Thomson state the degree of accuracy that we should secure, if we should adopt some uniform method of testing, that is, whether the meter should register within half of 1 per cent., or a quarter of 1 per cent, or what errors would be allowable.

MR. THOMSON. I think I did mention with reference to the sensibility test, that taking the minimum rate of one cubic foot an hour, in my judgment it is well within the power of manufacturers to turn out meters regularly that will indicate within 3 per cent. of accuracy at that rate. At the higher rates of flow, in my opinion, it is well within the power of manufacturers to produce meters that will indicate within 1 per cent. of accuracy, plus or minus. I am referring, of course to the domestic sizes, that is the smaller sizes of meters.

MR. RICHARDS. I think in this connection it might be well to consider how often in actual use a meter is required to register these extremely small streams. When a meter supplies a tank through a ball cock, it might have to supply a very small stream quite often; but that is about the only case that occurs to me, where these exceedingly small streams will be drawn, unless they are drawn purposely. So I believe with Mr. Thomson, that a meter should be purchased to fit the place in which it is to be used.

MR. MCNALLY. I think that these small streams are just the ones that we ought to try to measure if it is possible. We meet so many cranks, especially those of us who are connected with the registrar's department, when we try to collect our money, that we have a great deal to contend with, and I believe that those are just the streams that we need to look after; and if we can get a meter that is accurate, and we certainly can for we do get them right along,

that is the kind of a meter we want. Of course it is well known that water works at the present time are accepting meters that are within 2 per cent., either minus or plus; but it has been the aim of our superintendent and of myself to get meters that are either absolutely correct, or that favor the consumer if they are in error at all. We want to know for a certainty that we can show that that meter is either correct or that it is favoring the kicker. It is this consideration that has led us to say to the manufacturer: "We will not accept your meter unless it it is absolutely correct, or within 2 per cent. favoring the consumer," and we send them back unless they test that way.

I believe, as Mr. Thomson has said, that there should be some uniform method for meter testing, and that great care should be exercised in using it. We are now using discs which I think are not reamed out at all. Of course if he was testing a meter with the sharp edge reamed off as suggested in his paper, there would be quite a difference between his test and ours. I think there should be uniformity in testing, and when this is brought about there will be a better feeling between manufacturers and the water departments. It is a matter which will require considerable study, and it will benefit all concerned.

MR. HOLDEN. I would like to ask Mr. Thomson if, in his experience, there is any way in which a meter after it has once been adjusted can over-register? There are frequent complaints that meters are over-registering, but I never have been able to find one that did, and I would like to ask if a meter can get out of order in any way so it will over register?

MR. THOMSON. No, sir, I have never had that experience in my practice, and I don't understand how it could occur. I think it might be possible with some types of piston meters, but it will occur if at all very rarely and under very peculiar conditions, such as are not likely to arise in regular practice. I have heard that some waters deposit a sort of fungus growth upon hard rubber pistons and with them such a result has been observed, but it never has come directly to my knowledge. I think it is almost invariably the case that the meter, especially if it is run severely in practice, is liable to loose in sensibility, and therefore be in favor of the consumer.

I might say that there is one case of over-registration, which I may properly refer to here, that of the current or type of inferential meters which are quite largely used in Europe. Over-registration may be produced in such meters as the result of water ram and especially if there happens to be an air cushion in the meter, the wings or vanes of the meter being impelled forward by water reacting from the result of compression of the air, although no water is actually passing through the meter. But that type of meter has not been used in this country to any great extent.

MR. HASKELL. I would like to ask Mr. Thomson whether in the case of a piston meter operated under a high pressure, with a good deal of grit in the water, the piston might not wear sufficiently to produce over-registration.

MR. THOMSON. I really do not understand, sir, how that result could occur. It would reduce the displacing capacity of the piston.

MR. HASKELL. Suppose the piston is taken from a meter and filed down, then at each stroke of the meter the amount of water displaced would not equal that shown on the dial.

MR. THOMSON. The water would then slip by the piston and would not be shown on the indicator at all.

MR. WILLIAMS. Is the difficulty most likely to be in the slip past the piston or disc of the meter, or in the recording apparatus?

MR. THOMSON. It is very largely, if not entirely, in the displacing member of the mechanism, the piston on the disc or wheel, whatever it may be. Any change in the recording apparatus of the meter usually is in the line of increased friction, and therefore it slowly decreases the sensibility of the meter in a long period of time. That, however, affects it only at the lower rates of flow. The actual change, in the quantity of water displaced, comes from wear of the parts; and that is one reason, as I suggested in my paper, that meters should be in almost every instance somewhat adapted for the character of their service. In my judgment it is not good engineering to fit the meter to the very finest work in sensibility, and then expect that meter to stand up under the very highest rates of delivery. Take, for instance, a $\frac{5}{8}$ meter, which may be called on to deliver, say, 3 cubic feet a minute for one minute, and the next minute you expect it to indicate at the rate of a cubic foot an hour. Under such conditions the sensibility of the meter will almost invariably be lost, especially if there is grit in the water. Whereas if the

meter is free, and there is grit in the water, the meter will last longer, and be uniformly more accurate in its registration at the higher rates of flow.

MR. HOLDEN. Is it advisable for the meter manufacturer to make or for the meter user to use meters adapted for extreme accuracy? Isn't it much better to look for durability rather than for absolute accuracy? There are few places in the country where the rates for water are so high as to make extreme accuracy in measurement necessary. Our charge is about 50 gallons for a cent, 20 cents a thousand gallons; and isn't it better to give the consumer a few gallons and have a durable meter, rather than to have one which is extremely accurate, which will register down to a few drops, and which will last but a short time?

THE PRESIDENT. Gentlemen, this is a subject in which I have a deep personal interest, for I have come near getting scalped a number of times by people who, of course, didn't use any water and yet claimed that "The darned thing keeps running night and day." (Laughter.) If you will allow me just a word I will say that I have come to the conclusion that water is not so valuable a commodity but what we can afford for our own peace of mind to be sure that we are giving the consumer all we agree to give him for his money. When a kicker comes to us and we can show him that we are simply throwing water at him, that he is getting about 20 per cent. more for his money than he thought he was, then he will be satisfied, and he will tell his neighbor about it, and we will have a chance to put in two or three more meters. There are lots of consumers who think it is possible for a meter which has run accurately for six months to jump right ahead with an error of 50 per cent. against them. When you can put the meter on a bench and show him squarely and fairly that he is getting more than he is paying for, he goes away happy and settles up his bill and keeps the old thing churning, and everything is all right. But if he finds you a fraction of one per cent. in error on the wrong side, that is, against him, he will make you take the meter out and sharpen your pencil pretty fine in order to make the reduction on his bill. So for my part if I can get a meter that will run within 5 or 8 per cent. of accuracy, and have it run in favor of the consumer all the time, and have it durable, so that it is not necessary to strip it and clean it out to get it to run, and so that it will not break down but will keep going, and I can

be sure that I am not losing over 8 per cent. and with the price we are getting for our water, I don't believe but what the city is making money then, and it certainly saves lots of trouble for the man who is running the works.

MR. GILBERT. After having had 10 or 12 years' experience with meters, I agree perfectly with what the President has just said. I don't care to spend my time, and the money which we get for water, in trying to test these meters down so very fine, while we allow those consumers whose water is not metered to waste as much as they please. Give me a meter that will register nearly all of the water, that is within from 3 to 8 per cent. as the President has said, and I can make it pay and make the consumers happy. It has been my experience that when you get a meter that registers down within 1 per cent. you have a meter which is liable to stop, and I don't want to accept such meters. I don't think the small amount of water we should lose would amount to anything, in fact, I don't believe it would amount to half as much as we should spend in testing the meters.

MR. WILLIAMS. The point of greatest interest to me in this connection is not so much to know what we ought to expect from a meter as to know what we really do get in practice. There are some water works systems in New England, I believe, in which all the services are metered, and I think the general experience is that their pump records show about twice as much water as the meters account for, and I would like to discover the cause of the discrepancy. When we think that the average consumption in our ordinary towns for domestic supply is less than 3 cubic feet per day per person, and the average family is about five persons, it does not give an average of one cubic foot an hour, which is the rate according to Mr. Thomson, on which there may be three per cent. variation. And as the error appears to be in the displacing mechanism, corresponding to a slip in the pump plunger or through the valves, it must be possible for leakage to continue for the whole 24 hours at very nearly the same rate it would leak when the meter was moving at a slow rate, without its being recorded. So it seems to me that in those cases where the consumption is well down towards the minimum, that is where it is brought down to about 6 or 7 gallons per person, as it is in a good many places, the error in the meter must be very nearly 100 per cent. If that is so, it will account

for a good deal of the difference that we find between the records of the water meters and the pumps.

MR. HASKELL. It might be possible in a great many places to get even a greater discrepancy than that, as for instance, in the stock yards in Chicago, where it is stated that they had a meter there which was measuring one million gallons of water, and there was another pipe which was delivering forty-eight millions unmetered at the same time. Where they operate water works in that way, it would be hardly a fair thing to put on meters with a slight discrepancy. Now Mr. Thomson has stated to us that he is prepared to furnish us meters that on any stream a taker is liable to use, will measure the water within one per cent. I don't think he can quite call it one per cent., because, as I understand him, he means one per cent. under or one per cent. over, so it is really two per cent., and the other figure I understood him to give was was three under and three over, which means six per cent. variation, But there wouldn't be much of any water lost anyway when a meter is delivering these small streams. Now I don't believe there is any meter man in this room but will agree to do this with his meter. I know I have no difficulty in getting meters which will test within one per cent. If you are a little bit particular about your meters, and they know you want them accurate, and you tell them the streams on which you want to put them, they will furnish you the goods. There is no trouble about getting what you want if you insist upon it. There can be no excuse for putting a meter on which is going to register against the consumer. It puts you in a very bad position, when a consumer comes to you with his complaint, if you have to admit that you knowingly put on a meter that was going to oblige him to pay more money than he ought to pay, and we make it a point in our city never to put on meters that over-register. We mean to get as near to one per cent. as possible, and though we don't always get it, we do come pretty near it. I don't believe that there is the least difficulty in getting meters that will register within two per cent., and from that under, from almost any of the meter men who are here. This meter business has been growing very rapidly within the past few years, and the manufacturers are giving us good goods, and in my opinion we ought not to let up at any three or eight per cent.

MR. WINTHOP. In our system we pump directly into the circu

lation, the surplus going to a tank. We have a long line of 8-inch pipe nearly on a line between the pump and the tank, but going to a dead end beyond. A half-inch connection was made with this main near the end, some four or five years ago, and that was metered. The bills used to be very high, from $6 to $8 a month. The consumer complained of white water and lots of air. We took the meter off and tested it a number of times and found the meter correct, or very nearly correct, a little in favor of the consumer. He wanted it tested in its usual position, and I concluded to do so, and found that he was paying for air, and that the meter was registering about double the amount of water that came through it.

MR. CHASE. The function of a water meter is two-fold. First, it acts as a machine to aid in proportioning the cost of water among the consumers in proportion to the amount of water they use; and secondly, it acts as a sort of police in preventing waste. By keeping people from permitting the water to run to waste through leaky fixtures or otherwise, the consumer is afraid of the bill which the meter will run up by excessive use of water, and the mere fact of a meter being on will lead the consumer to look after the fixtures and not allow leaks to remain unattended to. Now it is all very well to talk about allowing 2, 3, 4 or 5 per cent. loss of registration, but if a meter allows 1 or 2 per cent. to pass without registration, the small leaks will grow in frequency when the consumer finds out the meter does not detect them. I think those of you who have such meters will soon find out you are furnishing a great deal more water than you are getting paid for. It is a pretty good meter, I think, that under ordinary conditions, after a little wear, will register accurately a cubic foot of water an hour. That in the course of a day amounts to 180 gallons. If that is running continuously, at an average price, we will say, of 20 cents per thousand gallons, that amounts to over $13 worth of water per year, and is just about the amount of water that a person would be entitled to who pays the minimum water rate. Now, if a consumer finds out that his meter does not register small leaks, he will take very little cognizance of them, especially those in the average water closet. For that reason I think it is not advisable to put on meters which will not register within 1 per cent. to start with, and they ought to be looked after pretty sharply to see that they do not get more than 3 or 4 per cent. away from accuracy.

MR. LOCKWOOD. I don't believe in encouraging meter manufacturers to make poor meters. They are now making meters that are quite accurate, and I think we ought to hold them there. We all know that after a meter has been in use a little while it naturally wears and will pass water without registering. Now if you start with 6 per cent. loss you are soon going to get up to 8 or 10 per cent. loss. We endeavor to keep our meters within 2 or 3 per cent. and I certainly should not recommend a meter that did not come nearer than 8 per cent.

THE PRESIDENT. I would say in connection with figuring on 8 per cent. that that was the loss on a small stream; if the stream is very small the meter does not register. If you are drawing only a cubic foot an hour, and your per cent. of loss is the same as at higher rates, the loss isn't very heavy in any case. I think we all want a meter which will register whenever there is any appreciable amount of water drawn through it.

Mr. NOYES. In other words, Mr. President, I understand that your idea is that on very small streams, as when a faucet is leaking drop by drop, you consider there should not be more than 8 per cent. error, and that this per cent. should not apply on the ordinary working of the meter.

THE PRESIDENT. That is the idea.

MR. NOYES. I think that Mr. Williams of Detroit has hit the matter about right. The great value of the meter, as I understand it, is to prevent the little wastes, the leakages from the faucets and water closets when the water is not being drawn. I know in my own house, that by being careless in not having the faucets fixed, I have had to pay quite a sum of money, an amount far in excess of what it would have cost to have had the fixtures repaired. There is one interesting point that Mr. Williams made, in regard to the very large amount of water that cannot be accounted for by meter registration. I have in mind an instance which we found during the investigation which has been recently made in connection with the proposed new water supply for the Metropolitan District of Boston in one town where the water was purchased entirely from a water company, and every fixture in the town was metered, and they could account, under the very best conditions, for only from 50 to 60 per cent. of the water. And I think that in other towns where the water is metered,

about the same ratio of water could be accounted for. In the case of Newton, where, a very large percentage of the fixtures are metered, and by assuming for the remainder, the rate of consumption per person, as determined by Mr. Whitney in his series of observations made at Newton a few years ago, (the results of which were published in the*_Journal_ of the Association), the actual consumption is much greater than the amount of water which can be accounted for by the amounts measured.

MR. GILBERT. Perhaps I ought to explain my position a little more in regard to this matter. I don't want any of you gentlemen to think that I believe in poor meters. We have had considerable trouble with meters regulated so closely that they would gradually record less and less and finally stop. I think the loss would be less by having a meter which was not so closely adjusted that it would gradually stop. I think if you get a meter which will run regularly and will not stop, even if there is a small loss, it is better in the end.

MR. MCNALLY. I think the conditions of the work should govern the selection of meters. If the works have water with but little grit in it, it is certainly possible to use a meter that is built a little closer, and in which there is not such chance for slip as there must be in a meter passing a mixture of sand and water. Of course we don't want a meter to measure drops, but the manufacturers can make meters that are strong enough to wear ten years. We have taken them off and tested meters that had been on services for ten years and we have found that they had stood the wear in good shape and tested all right.

In regard to accounting for the water, it would seem to me that if the taps are all metered, and the meters are not indicating all the water pumped, other parts of the system should be examined for leaks. Joints, for instance, may need attention. It is certainly unfair to blame the meters for not showing the amount of water, instead of looking in the ground, or in the culverts, and elsewhere to find where the water is escaping, perhaps through the fault of some contractor who made the joints out of oakum and used very little lead. I think that will account for a good deal of lost water.

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*Vol. VI. p. 39.

A MEMBER. I think if our meter manufacturers can give us a meter which will register within 5 per cent. of the amount of water passed, and which will give us no trouble in repairing, cleaning, etc., we ought to be satisfied. When a man knows that a meter has been put on his service, that knowledge is enough to prevent him from wasting water, and he is going to use just as little water as he can. As far as detecting leaks is concerned, we look to our inspector for that, and what few leaks do not come under the observation of the inspector would not amount to a great deal.

MR. THOMSON. May I say just a few words more. If the President had stood by his first proposition, I think we could make his meters in a brass foundry. In reference to the moral effect of a meter, I have a friend who believes that a meter casing without any interior is amply sufficient to do the business. (Laughter.) I believe Mr. Williams, of Detroit, made a point, if I understood him correctly, which I did not intend to convey in the paper, namely, referring to an error, we will say of 5 per cent., if you like, in the meter at a low rate of flow, and by that I mean in a domestic size indicating down to 1 cubic foot an hour. Now that error need not continue at the higher rates of delivery, except possibly when the meter is driven at a very high rate of flow. If it is driven at a very high rate then it may under-register, because the water will be driven by it. But any of the rotary meters on the market today, can be made to indicate within 3 to 4 or 5 per cent. of accuracy on a rate of 1 cubic foot an hour, and that error will not be shown in the registration at the higher rates of flow. When you get a rate of flow of say 1½ or 2 cubic feet an hour, and from that up to the proper capacity of the meter, the registration of the meter should be, and almost invariably will be, accurate; and the original slip or error at the very low rate need not show at higher rates. And the same with regard to the point made by the President. The error at the minimum rate may be 8 or 10 per cent., and yet not be shown in the registration of the meter at the high rates of flow.

There was a point made by Mr. Noyes that I think has been very fully brought out in a paper recently presented to the American Society of Civil Engineers by Mr. Dexter Brackett, and which I believe will be published in probably the next number of its trans-

actions.* I think the data that Mr. Brackett has collected in regard to the subject are of the very greatest value. As I recollect he referred to Yonkers, to Worcester, to Fall River, and I know to Woonsocket, and I must say I was greatly surprised to find so great a discrepancy possible. I was surprised to find, as is set forth in my discussion of Mr. Brackett's paper, that the difference in the amount indicated by the meters and the amount which they believed they pumped, could be accounted for in almost all of those instances by a rate of flow of a cubic foot an hour on each of the services of the several cities and towns. It amounted to a great deal more than I thought was possible.

MR. HASKELL. We have heard a good deal about the loss of water, and all of us ought to know something about where there is a loss of water in our water supply systems. If a person will think for one moment of the amount of water that can escape in 24 hours through a $\frac{3}{4}$-inch pipe or a $\frac{5}{8}$-inch pipe, and then look at some of the water-closets and at the streams of water that run into them,—and if he wants to get instances of that he can send an Inspector around in any town or city and he will find a half dozen water-closets tied down and running full streams,—he will know where a great amount of water is wasting. I don't believe there is one of us but what can find such cases. I know my men are finding them almost every day, and it doesn't take many of them to account for a good deal of discrepancy between the amount of water pumped and the amount metered.

MR. WILLIAMS. Mr. President, I think from the reply which was made to my former remarks, that they must have been somewhat misconstrued. Let us assume that an average person requires 3 cubic feet of water per day, and that the average family consists of five persons, that calls for 15 cubic feet of water to be delivered through the ordinary domestic meter in 24 hours. Now your error of 3 per cent. at the rate of one cubic foot per hour will account for about $\frac{3}{4}$ of a cubic foot of water, which is lost. The 3 per cent. at that rate is going on for the whole 24 hours, whether the meter is moving or not, if there is a leak and with a flow of that sort, it may come up to very nearly a cubic foot in a day. Now take a case where the consumption is down so that instead of its

*Trans. Am. Soc. C. E. 758, Vol. XXXIV., Sept. 1895.

being 3 cubic feet per person per day, it is, say, but ½ of a cubic foot per person, as it is in some cases, and you will see that that same loss may occur and be going on continuously. So that where a family is actually using, or is assumed to use 2½ cubic feet of water per day, and the meter registers that, the actual consumption is 3½ cubic feet, or it might be even more than that. That is what I mean by saying that the percentage of loss would increase very greatly on smaller services. Now, as a matter of fact, in the city of Detroit about 20 per cent. of our services are such as we would expect to consume under 8 gallons per person per day, and 80 per cent. of them consume less than 20 gallons per person per day. So it is apparent that the chances are that errors will result vastly greater than 3 per cent.

A MEMBER. Where meters are applied on Chinese laundries, John quickly finds out the maximum rate of flow, which his meter will not indicate, and then he collects the water in his pans and tubs at that rate of flow. (Laughter.) In that case it is necessary to have a meter which will be of the very highest sensibility, and sometimes meters have been put in which would over-register a little bit at the higher rates of flow, and in that way the accounts have been balanced.

MR. COGGESHALL. We have a Chinaman in our town who can give that one points, for he takes the water out of the public drinking fountain. (Laughter.)

MR. BOOKE. I would like to ask the gentleman from Detroit if he has considered whether his pumping machinery is delivering water at every revolution as he expects it to? It strikes me that there may be loss there. I know we found it so in Princeton. Nine years ago it was a problem with us how we were to continue to supply water from the source we then had with the demand which was being made upon it. The meter companies came to our relief. We put meters upon every tap upon our mains, except the hydrants, and today we are not supplying a drop of water to any one except through meters. We immediately increased our revenue 100 per cent., and we have increased the number of consumers 100 per cent., and we are doing this with the same amount of water we were pumping nine years ago. And so I favor the meter manufacturers, and I think we ought to encourage them all we can.

THE PRESIDENT. We have discussed this question pretty thoroughly, and I think we have obtained much information, and some of us, perhaps, have said some things which we did not exactly believe ourselves. (Laughter.) Five to eight per cent. of error seemed to scare some of you when I mentioned it, but when a metre man said he would give you a meter which would register within three per cent. over or under, and that is six, that did't seem to frighten you at all. Now I think perhaps we have been here long enough, you have given very close attention, and as it is now after 5 o'clock we will adjourn untill evening.

TESTS OF ARTICLES OF COMMERCE, TO BE CONDUCTED BY THE ASSOCIATION.

BY

CLEMENS HERSCHEL, Supt. East Jersey Water Co., New York.

[Read September 12, 1895.]

It may be known to many of our members that the Pennsylvania railroad has a testing laboratory at Altoona, Penn.; an establishment employing from twenty to forty skilled men, among whom are several prominent civil and mechanical engineers, chemists, asssistants and mechanics. It is their duty to advise the company in the purchase of materials of every sort, whether a manufactured article, such as car-springs, boiler-tubes, and the thousand other things purchased on a railroad like the Pennnsylvania; or substances that may more properly be called raw materials, such as oils, paint, iron, steel, etc.

To do this intelligently, the laboratory is constantly engaged in tests of articles of commerce, as supplied by different makers and dealers. That it pays to conduct such a laboratory, its existence and appreciation on a railroad like the Pennsylvania, for the past twenty years, should be sufficient proof.

Similar work to that done by the Altoona testing laboratory has also been done by the American Association of Railroad Master Mechanics. Quite recently a committee of the association has reported the results of tests of some twenty odd makes of brake-shoes, now on the market.

The Manufacturers Mutual Fire Insurance Company of Boston, does similar work in behalf of its members, and reports the results by circular.

Wherever a body of men are interested in having such work done, it is evidently economy to have it done and the results reported at the common cost, rather than to leave each one to shift for himself.

It is therefore proposed that the association shall, from time to time, cause sets of tests of the sort described made at the expense of the association, by committee or otherwise, and that the results be reported by circular or in the JOURNAL.

As a beginning in this direction, I suggest a test of all the ordinary house water meters, now on the market. A test of this

sort, it will be remembered, was made by the city of Boston in 1888. But such has been the rapid advance of meter manufacture since then, that the results of 1888 are of no use in 1895. Few of the meters then tested, are yet manufactured, and many new ones have since then been put upon the market. And it may well be, that, tests now made, would have to be repeated once or twice, at intervals of seven years, in order that false principles and methods of construction may get definitely culled out, and the manufacture of water meters be put upon a satisfactory basis.

The reason I have suggested the test of water meters as a beginning, is because I have had a little experience in this direction during the past winter, which I will describe for the benefit of the association; and from which the association may judge for itself whether tests such as are here recommended are instructive or not.

I bought in December, 1894, one each of seven different makes of $\frac{5}{8}''$ water meters, which, for the present, I will call 1, 2, 3, 4, 5, 6, 7.

They were tested for accuracy, and for loss of head caused by the meter, at various rates of discharge. Then about 100,000 cubic feet were allowed to pass each meter, and the first set of tests were repeated. Then some 150,000 cubic feet additional were allowed to pass each meter and the first named tests were again repeated. The quantity passed was equivalent to some ten years of ordinary use.

Incidentally, therefore, these tests comprised a test for durability. Tests were also made for sensitiveness; and a test for remaining unaffected by long continued disuse, is still under way.

The results were somewhat remarkable. They are given in the following table:

	First Test. Rank.							Second Test. Rank.							Third Test. Rank.						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy. . . .	2.	1.	6.	7.	5.	3.	4.	1.	2.	3.	4.	5.	6.		1.	2.	3.	4.	5.	6.	
Sensitiveness	1.	5.	2.	3.	4.	7.	6.	1.	5.	2.	3.	4.	6.		same 1.	same 2.	same 5.	same 3.	6.	4.	
Permanency.								4.	1.	2	3.	5.	6.		1.	2.	4.	3.	5.	6.	
Loss of Head	4.	1.	7.	3.	2.	6.	5.	4.	1.	3.	2.	6.	5.		4.	1	3.	2.	6.	5.	
Price.	1.	same 3.	same 2.	6.	7.	4.	5.														

I will call attention to only one point: the three cheapest meters have been shown to be the three best ones; and I will leave it to the business sense of the members of this association whether a result of that kind is not worth discovering.

It would not be assumed, to begin with; and would hardly be matched were the tests to be made of watches, clocks, shot-guns or bicycles. It has often been claimed that "the cheapest is the best," but here is a case where the best is the cheapest.

It may be that a test of all the meters now on the market, would modify the conclusions reached from this reported test of only seven of these meters, but the point sought to be presented to the association is, that it pays to test articles of commerce, and that such work, to be undertaken for the benefit and instruction of its members, is a proper thing for this association to undertake and pay for.

To do so would be entirely in line of furnishing instruction to its members that cannot otherwise be obtained, which has so prominently obtained as one of the duties of the association hitherto.

DISCUSSION.

THE PRESIDENT. As I understand it, Mr. Herschel suggests that the association should take up the matter of testing different meters and stamping them with its approval or disapproval, or with the results of the tests, and that the tests should be made at the expense of the association, for the benefit of us all. The subject is now open for discussion. Have the meter men all gone home? (Laughter.) If they have, the meter users have not. We would like to hear from Mr. Cook of Woonsocket. I think he has some ideas on this subject.

MR. COOK. There are various kinds of meters in the market that are doing good work, and I was very sorry yesterday to hear some member say that within four or five per cent. of accuracy was good enough for a meter. I don't want the meter manufacturers to get the idea that we are going to be satisfied with that kind of a meter. I know that it is impossible to get a meter that will register accurately in all cases, with low flows and also with high flows, but the meter which is demanded in houses with modern plumbing is a meter which will detect a small leak, but which will also allow a man to use his lawn sprinkler, and will measure both accurately.

MR. NOYES. The idea advanced by the writer is certainly a novel one, and since I have heard the paper read I have been turning over in my mind the practicability of having such tests as Mr. Herschel suggests made by the association. It seems to me that while the idea has some things in its favor, it would be very difficult to carry it into execution. Mr. Herschel himself has apparently found that in speaking of the tests he has made, it is not prudent or proper to speak of the various makes of meters, but he has designated them only by numbers. Now, the test which he refers to as having been made by the city of Boston in 1888, was conducted by honorable men, who were above reproach, and yet that test was severely criticized by men who were interested in the various meters.

It has seemed to me further that the conditions under which meters have to work are so different in different places that any test which might be made under the auspices of the association, might not be satisfactory for all the conditions encountered in various works. I think it is perhaps within the scope of this association to formulate methods of testing which might be more satisfactory than those now in use, but it does seem to me that the testing itself must be done, and the decisions reached by the individual departments, and that the officials in each place must determine what meter is best for their particular use.

THE SECRETARY. In reference to the Boston tests, it might be well to say that as a result of those tests, which cost, I think, some ten or twelve thousand dollars, the meter which was considered the best by that commission has never been known commercially, and the meter which was considered the second best has had only a very limited sale.

MR. NOYES. That is, in practice, the meter which had given the best test proved to be a practical failure.

THE SECRETARY. It was a failure commercially.

MR. THOMAS. A few years ago an attempt was made to get the Massachusetts legislature to provide for the appointment of a special commission to test meters and approve them, and the members of this association were practically unanimous in their opposition to it, quite a number of them presenting themselves at the meeting of the legislative committee on water and opposing it. And I think that if a committee of this association were to test the various meters now on the market, the result would be that it would approve of every

one of them. I think that if the plan proposed by Mr. Herschel should be put into practice by this association it would be a complete failure.

MR. NOYES. My attention has been called to one difference between the test proposed and those which are spoken of in the paper as having been conducted by the master mechanics of various railroads. The great benefit derived there is the securing of uniformity, which is necessary on account of the interchange of cars between the railroads, and the consequent necessity of having uniform appliances.

MR. HASKELL. Mr. Herschel's paper presents in a general way some reasons why this association should go into the meter business. The time has not yet arrived, I think, when we ought to do that. Then, again, any water department that hasn't ability enough among its own members to test meters properly, could not, I think, be assisted by outside help so that it could run its business any better. (Laughter.)

MR. SMITH. It seems to me that it is eminently the duty of this association to adopt, as other societies have done, a comprehensive and uniform system of testing water meters, so that we may have the benefit of comparisons of tests made upon a common basis. I think that was recommended very strongly yesterday by Mr. Thomson, and I believe that such action by the society would be a great benefit to all of us, both the users and the manufacturers of meters.

PROF. SWAIN. Mr. President and fellow members: I agree thoroughly with what Mr. Noyes and Mr. Smith have said in regard to this subject. It seems to me that any association of this kind, any scientific or technical society, should avoid the thing that Mr. Herschel suggests, that is, going into the testing of commercial appliances and reporting the results. I think the proper function of such a society, when it is asked to do anything in that line, is simply to lay down standards for tests. I have been trying to recall any case where a society of this kind has gone into the work of commercial testing, but I have not been able to think of one. Societies have adopted standards for testing materials, boilers, etc., but I do not think of any that has ever gone into commercial testing and reporting of the results. A good many of our members, both active and associate, are interested in meters, but it does not strike

me as quite the proper thing for this society to go into the business proposed. I should think that the work of testing should be left to the companies, individuals or communities using the meters, just as the testing of materials used by railroads is done by the several railroad companies, and not by any railroad association.

MR. RICHARDS. I do not see why we should do anything more as an association than to indicate the methods by which tests should be made. When it comes to making the tests and telling which meter is the best one in our opinion, it is very possible that we might differ among ourselves; and I see no reason why we should do so any more than we should test cast-iron pipe and tell which manufacturer in our opinion, makes the best iron pipe or who makes the best hydrants or gates. We might indicate the proper tests for all these things, but I see no reason why this association should make the tests. That would be an interference with commerce.

MR. HERSCHEL. In closing the discussion by letter several months after the event, what evidently demands the most attention, are misconceptions, to be set right.

The President starts the discussion by saying, that, as he understands it, meters are to be stamped with the approval, or the disapproval of the association. But no such suggestion is made in the paper. It is one thing to give an opinion; it is quite another thing to report facts, and let the reader form his own opinion. In the paper, I suggest the determination and the reporting of facts, being the results of tests; and whatever opinion any member chooses to draw from determined and reported facts, he should be welcome to. If certain meters cannot bear the statement of the facts appurtenant to them, it is no duty of any member of the association to aid in the preservation of ignorance concerning these and other facts.

Mr. Noyes infers that I did not think it prudent, or proper, to mention the names of the meters tested. I did not do so, because I wanted the association to have the honor of a first publication for itself, and because a publication of meter tests should be made following an exhaustive test of all the makes of meters on the market; whereas, I had tested only seven. The conditions referred to by Mr. Noyes, under which meters work in practice, could, and should, all be reproduced in a series of tests. The same tests could also be made with different waters, as found at different places. I see no difficulty on that score.

Mr. Noyes' later remark, that the work of the Railroad Master Mechanics' Association was in line of striving for the uniformity that is requisite in the interchange of cars, is singularly inappropriate for the case cited, of tests of brake-shoes; in which the only thing sought for, is the greatest amount of wear of brake-shoe, for a dollar's worth of shoe.

The Secretary says, the meter considered best by the 1888 Boston commission, "has never been known commercially." This and two succeeding references to the underlying fact, are all expressions of many possible meanings. As I understand history, the meter referred to has never been placed on the market; and as not being on the market at the time, ought, perhaps, never to have been tested. It would certainly be a good rule to test only meters that have had a certain prescribed extent of sale with the public. Otherwise, models could be sent for test, and excellent results could be achieved by meters that cost impracticable sums of money to manufacture.

Mr. Thomas is under the impression, being perhaps misled by the President's introduction, that the association is to approve, or disapprove of meters, and that to attempt this would be "a complete failure;" and I think it would be, to attempt this thing. But that does not militate against a plan to have the association determine facts for the benefit of its members, and to give the members the benefit of facts procured by joint labors and at the joint expense.

I suggest to Mr. Haskell, that the association could make a series of tests of meters which, in completeness of results gathered, would be beyond the ability, pecuniary and otherwise, of many members of the association.

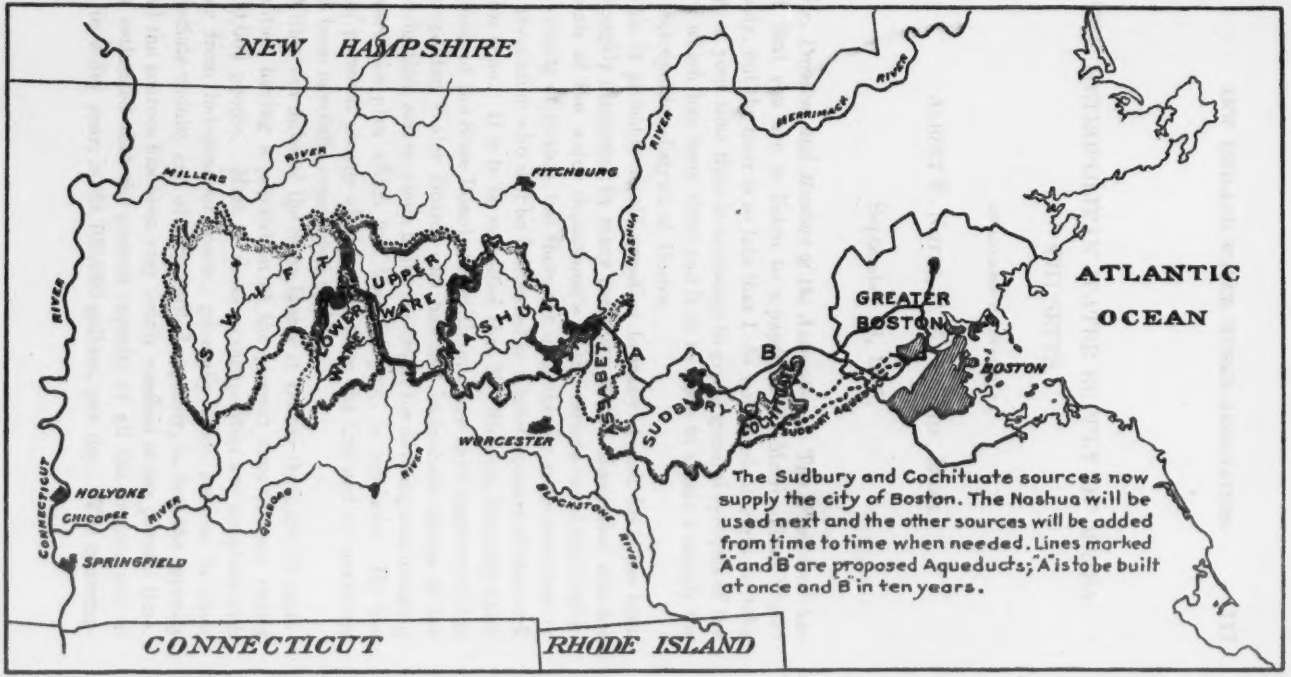
Prof. Swain cannot "recall any case where a society of this kind has gone into the work of commercial testing." I mentioned the Railroad Master Mechanics' Association, a very parallel case to our own association, and I could undoubtedly find others, here and abroad. The reference made by Prof. Swain to no tests being made by any railroad association, is again unfortunate, for he surely must know of the railroad associations that test patents, and report the results to the members of the association. Prof. Swain himself has tested trolley-car fenders, and other railroad and railway appliances, and reported the results for the benefit of trolley railways, and of railroads, and of the traveling public. This, no doubt, was a severe ordeal for poor contrivances and inventions to pass through, but it

was a welcome one for the good contrivances to be called upon to encounter.

To me, the difference between a mutual insurance company, a railroad company operating many railroads, or an association of railroad companies, or a railroad commission paid by the railroads of a certain state; a master mechanics association, or an association composed principally of water works superintendents; in each case doing work in which all are interested, at the joint expense of all, and with the intent of letting all know the results of such work—is no such difference as is worthy to be named.

As for either the felt, or an expressed fear of interfering with commerce, that must, at the last, stand for mere cowardice. This is a world of survival of the fittest. Nobody can complain, if observed facts go to show that this, that or the other thing has become unfit.

The several public tournaments of turbine wheels that have been had in the United States, undoubtedly took a great many gimcrank turbines out of the market, some of them of an alleged one hundred and more per cent. efficiency; but they have reduced the number of makes of wheels on the market, as no other process could have done, and have been a blessing to the buyer of turbine water-wheels for all time. A little of this sort of sifting out, would further the use of meters, and would improve the make of meters on the market, in one year, as no twenty years will otherwise accomplish. And to accomplish this, I again submit to the association, is a worthy and proper thing to do by a body of water works superintendents associated, as they should be, for the common good.


NEW HAMPSHIRE
MILLERS RIVER
FITCHBURG
MERRIMACK RIVER
NASHUA RIVER
CONNECTICUT RIVER
SWIFT
LOWER
UPPER
WARE
NASHUA
WORCESTER
QUINSIGAMOND RIVER
BLACKSTONE RIVER
HOLYOKE
CHICOPEE RIVER
SPRINGFIELD
CONNECTICUT
RHODE ISLAND
SUDBURY
COCHITUATE
SUDBURY AQUEDUCT
A
B
GREATER BOSTON
BOSTON
ATLANTIC OCEAN
The Sudbury and Cochituate sources now supply the city of Boston. The Nashua will be used next and the other sources will be added from time to time when needed. Lines marked "A" and "B" are proposed Aqueducts; "A" is to be built at once and "B" in ten years.

CONNECTICUT
RHODE ISLAND
NEW HAMPSHIRE
ATLANTIC OCEAN
BOSTON
CONNECTICUT
MERRIMACK
PISCATAQUA

THE METROPOLITAN WATER SUPPLY OF MASSACHUSETTS.

AN ADDRESS DELIVERED BY

ALBERT F. NOYES, C. E., BOSTON, MASS.,

September 13, 1895.

Mr. President and Members of the Association: The President has said that you are to listen to a paper on the Metropolitan Water Supply, but the hour is so late that I do not think it right to take more of your time than is necessary to give a general synopsis of the work which has been done and is to be done to obtain a supply for the metropolitan district of Boston.

This is probably an old question to many of you, for it has been thoroughly discussed by many members of the association who are officials of the water departments of the various municipalities in the vicinity of Boston, but there are undoubtedly some members of the association who will be interested in a brief account of the work at this time. It is to be regretted that Mr. Stearns, formerly chief engineer of the State Board of Health, and now chief engineer of the Metropolitan Water Board, who has had immediate charge of the investigation, and to whom is due the credit for devising and bringing forward the plan which has been adopted, is not here. He has taken personal charge of the work from the first and all questions have been carefully considered by him.

Within ten miles of the State House at Boston there are 28 municipalities, having a population at the present time of very nearly 1,000,000 people. Most of these municipalities are supplied with water from independent works, generally from sources in their immediate vicinity and of very limited capacity, in fact the capacity of all the sources has been very nearly reached at the present time. It is estimated that the present capacity of all the sources now in use, in a dry year, is 83,700,000 gallons, per day. The consump-

tion of water in 1894 in the metropolitan district was 79,043,000 gallons per day, or 21,000,000 gallons more than was required in 1890.

The only sources which furnish water of suitable quality, and which could be made to supply more than 4,000,000 gallons each per day, are the Boston and Cambridge sources. The Boston sources when more completely developed will have a capacity of 62,000,000 gallons per day, and the Cambridge sources 13,000,000 gallons per day. The Boston sources, exclusive of Mystic lake, which should be abandoned on account of the inferior quality of its water, lie from 15 to 30 miles westerly from the city. It is to be regretted that the large map which has been prepared was too large to be brought here, but a smaller map, which may be seen by some of you clearly, and which can be examined later by any who wish, shows the various watersheds that are in use at the present time for supplying the city of Boston; and it also shows the watersheds which it is proposed to bring to Boston as they are required as a source of supply for the district, and which I will describe later.* I would state that this colored area is the watershed of the Mystic supply, which was originally taken by the city of Charlestown, and which now supplies the Charlestown, Chelsea and Everett districts. The blue color represents the Cochituate watershed, which was the first water supply of the city of Boston outside of its own limits. The red color represents the watershed of the Sudbury river, which was brought into use by the city of Boston between 1875 and 1880.

The Cochituate and Sudbury supplies are connected with the Chestnut Hill reservoir, the principal distributing reservoir of the city, by aqueducts capable of carrying much more than the sources will now furnish.

All sources within 100 miles of Boston were considered, but only three were found worthy of special investigation. These three being the Merrimac river, above Lowell, Lake Winnipiseogee and the Nashua river which was adopted.

After careful and extended study it was estimated that the population of the Metropolitan district would reach 2,000,000 in 1920, and that the average consumption of water at that time would be nearly 200,000,000 gallons daily, and no source of supply was con-

*See Plate I. for general location of water sheds now in use and those to be added.

sidered unless capable of being so developed as to yield this quantity of water in connection with the existing supplies.

Among the smaller sheds which are incapable of yielding this quantity might be mentioned the Ipswich river which is north of the metropolitan district and has a drainage area of 97 square miles above Topsfield. Further up, near the insane asylum at Danvers there is a favorble point for taking a water supply from it, and there the watershed has an area of 54 square miles. It is probable that sites could be found for storage reservoirs large enough to allow supplies of 29,000,000, or 16,000,000 gallons daily to be obtained from the points mentioned respectively; but these are obviously too small quantities to be seriously considered for metropolitan water supply.

The lakes in Plymouth county, particularly the largest of them, Assawompsett pond, were considered, but the supply that could be obtained was insufficient, and it was already in use to supply water to the municipalities in the southern portion of the state, New Bedford and Taunton, and possibly will be required in the future for other municipalities, Brockton or Fall River. So it was out of the question to try to develop these sources, aside from the large cost of having to pump the water, which is avoided in the Nashua river plan adopted.

The Charles river and the Shawsheen river were also considered, but the limited area of the Shawsheen watershed and the heavy population upon that of the Charles prevented their adoption.

Lake Winnipiseogee was more seriously considered. It was found that it would be necessary to construct a conduit some 84 miles long, and that the supply that could be obtained from the lake by drawing it down five feet when necessary would be 208,000,000 gallons per day, and the estimated cost, not including the water damages, was $34,000,000. The heavy cost of construction, together with the large cost which would be involved for water damages, precluded its further consideration. Lake Sebago, near Portland, was also considered, but its great distance from the city and the great expense of obtaining the water, aside from the cost of pumping, did not warrant the adoption of that source of supply.

The Merrimac river, above Lowell, was also considered. Owing to the very large population of the cities upon its banks the water of

the river is entirely unfit for use in its natural state, but it could be purified by suitable sand filtration. Plans and estimates were made for such filtration, but the cost, including the capitalized cost of pumping and filtration, was $17,463,000, or nine-tenths as much as the estimated cost of the Nashua river project, and the board decided that the increased cost of the latter was more than offset by the advantages of natural purity and of a gravity supply, and so this was also thrown out of consideration.

The State Board of Health has had charge of the water supplies for several years, and this work has been under the personal supervision of Mr. Frederic P. Stearns, their chief engineer, from the time of his appointment in 1887 until his recent appointment as chief engineer of the Metropolitan Water Board. In his investigations Mr. Stearns early came to the conclusion that a Metropolitan water supply would be necessary, and his attention was called to the watershed of the south branch of the Nashua river, which is just beyond the Sudbury watershed and above the city of Clinton.

Immediately above the Lancaster Mills in Clinton there is a very favorable site for a dam. An area of 6.5 square miles, shown on Plate I., will be flooded by the construction of a dam 145 feet high and 1,250 feet long, and the reservoir thus formed will contain 63,000,000,000 gallons. The enormous storage capacity as compared with other celebrated reservoirs is well shown by Table I. From this you will see that reservoir No. 6, the recently constructed and largest of the reservoirs connected with the Boston system, holds only one-ninth as much water as the dam to be built upon the Nashua river. The new Croton dam for the supply of New York city, although considerable higher, has a capacity only one-half as great, and the world renowned dam at Vyrnwy, Wales, for the supply of Liverpool, has less than one-fourth of the capacity of the Nashua river dam.

The estimated cost of the reservoir with the land to be taken for its site is over $9,000,000. This sum includes the cost of removing from the site of the reservoir all of the surface soil and everything containing more than a very small amount of organic matter.

It is calculated that in a dry year this reservoir will yield 105,000,000 gallons of water per day, which taken in conjunction with the present Boston supplies from the Cochituate and Sudbury rivers, will make a total yield of 173,000,000 gallons per day.

TABLE I.

COMPARATIVE TABLE OF AREAS, DEPTHS AND CAPACITIES OF STORAGE RESERVOIRS, WITH HEIGHTS AND LENGTHS OF DAMS.

Name and Location of Reservoir.	Area Square Miles.	Average Depth, Feet.	Maximum Height of Dam.		Length of Dam, Feet.	Capacity Million Gallons.
			Above Ground.	Above Rock.		
Swift River, Mass	36.96	53	144	...	2,470	406,000
Nashua River, Mass	6.56	46	129	158	1,250	63,068
Nira near Poona, India	7.25	27	100	...	3,000	41,143
Tansa, Bombay, India	5.50	33	127	131	8,770	37,500
Khadakvasla, Poona, India	5.50	32	100	107	5,080	36,737
San Mateo, Cal.	.....	..	170	...	.....	32,000
New Croton, N. Y.	... .	..	157	225	1,270	32,000
Elan and Claerwen, Birmingham, Eng., water works total of six reservoirs	2.34	43	98 to 128	...	4,460	20,838
All Boston water works reservoirs combined	5.82	14	14 to 65	...	.....	15,867
Vyrnwy, Liverpool, Eng.	1.75	..	84	129	1,350	14,560
Ware River, Mass	1.62	33	71	...	785	11,190
Sodon, N. Y	.....	..	72	89	500	9,500
Hemet, San Jacinta, Cal	. ...	..	150	...	200	8,500
Reservoir No. 5, Boston water works	1.91	19	65	70	1,865	7,438
Titicus, N. Y	.....	..	105	115	.....	7,000
Hobbs Brook, Cambridge water works	1.00	12	23	...	.....	2,500
Cochituate, Boston water works	1.35	8	...	...	.....	2,160
Reservoir No. 6, Boston water works	0.29	25	52	...	1,500	1,500
Furens, France	.....	..	146	184	.....	422

NOTE.—The heights of dams are given from the ground and rock up to the level of full reservoirs. The lengths of dams are the distances across the valleys at the level of full reservoirs on the line of the main dam. The capacities are given in United States gallons.

As the time is so limited I will not detain you with too many statistics, but will merely call your attention to some of the more interesting features which are shown by the tables and diagrams herewith presented.

In Table II. are shown the estimated populations of the Metropolitan district by five year periods up to 1930, and the estimated consumption of water. The increase in the consumption of water during recent years has been much more rapid than the increase in population, owing in part to the introduction of a greater number of fixtures, allowing more leakage, and in part to the greater demands for water for manufacturing purposes.

TABLE II.

ESTIMATED POPULATION AND CONSUMPTION OF WATER IN METROPOLITAN DISTRICT FOR EACH FIVE YEARS FROM 1895 TO 1930.

Year.	Estimated Population.	Daily Consumption per Inhabitant, Gallons.	Total Daily Consumption, Gallons.
1895	984,301	85	84,000,000
1900	1,148,033	90	103,000,000
1905	1,328,787	94	125,000,000
1910	1,526,623	97	148,000,000
1915	1,743,510	99	173,000,000
1920	1,979,930	100	198,000,000
1925	2,238,500	100	224,000,000
1930	2,521,875	100	252,000,000

Plate II. shows the cross section of the dam at the Nashua basin and corresponding sections of certain other notable dams drawn on the same scale. This shows how advantageous a point has been selected and how small the dam is in comparison with the other dams in proportion to the quantity of water stored. Fig. 3 shows on a larger scale a cross section of the Nashua dam in greater detail.

The general location of the dam with reference to the Metropolitan district is shown by Plate I., which also shows the aqueduct which will be constructed to carry the water to basin No. 5 of the present Boston water works on the upper section of the Sudbury watershed, from which point it will flow through existing aqueducts to Chestnut Hill reservoir for the present. When the capacity of these aqueducts is exceeded an additional aqueduct will be con-

structed to Spot Pond, as shown by the map. The aqueducts now in use are shown by dotted lines, and those to be constructed by solid black lines.

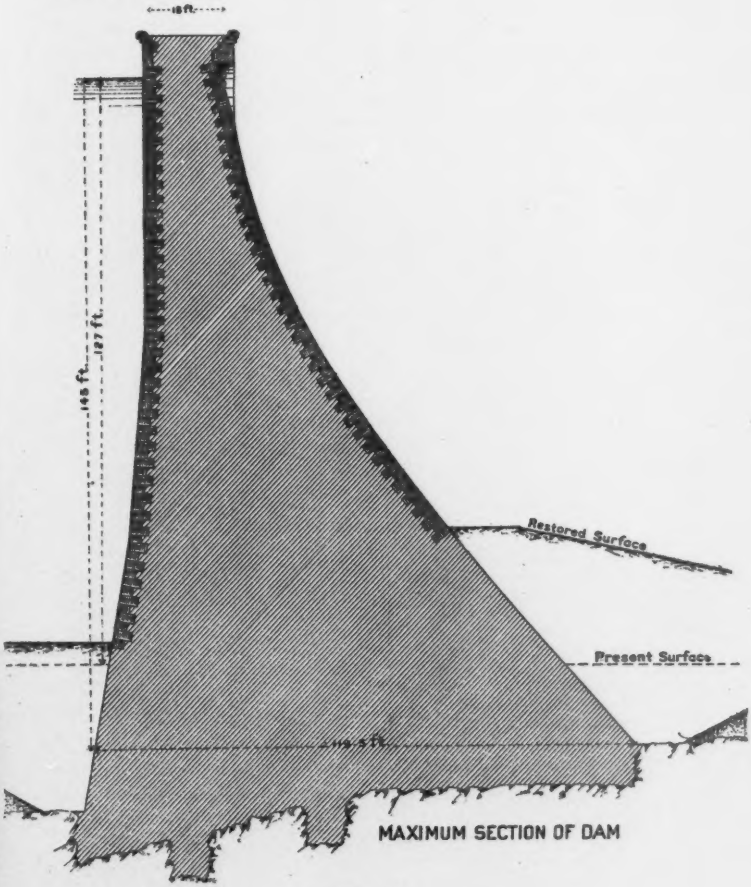


FIG. 3.

The first addition to the supply will be made by adding a portion of the Assabet river watershed. The next addition will be made by constructing an aqueduct from the Upper Ware to the Nashua river,

and a reservoir can be constructed which will still further increase the supply. With the addition of the Assabet the available supply is estimated at 201,000,000 gallons, and with the Upper Ware at 272,000,000 gallons daily, and at some time in the future when it has become necessary to add the Lower Ware and the Swift rivers to the supply, the estimated capacity will be 472,000,000 gallons per day, with the Deerfield river still to the westward and capable of being added if required.

Table III. shows the various watersheds investigated and some others for comparison, with their populations per square mile and the colors of the waters obtained from them, and also the relative hardness of the various waters.

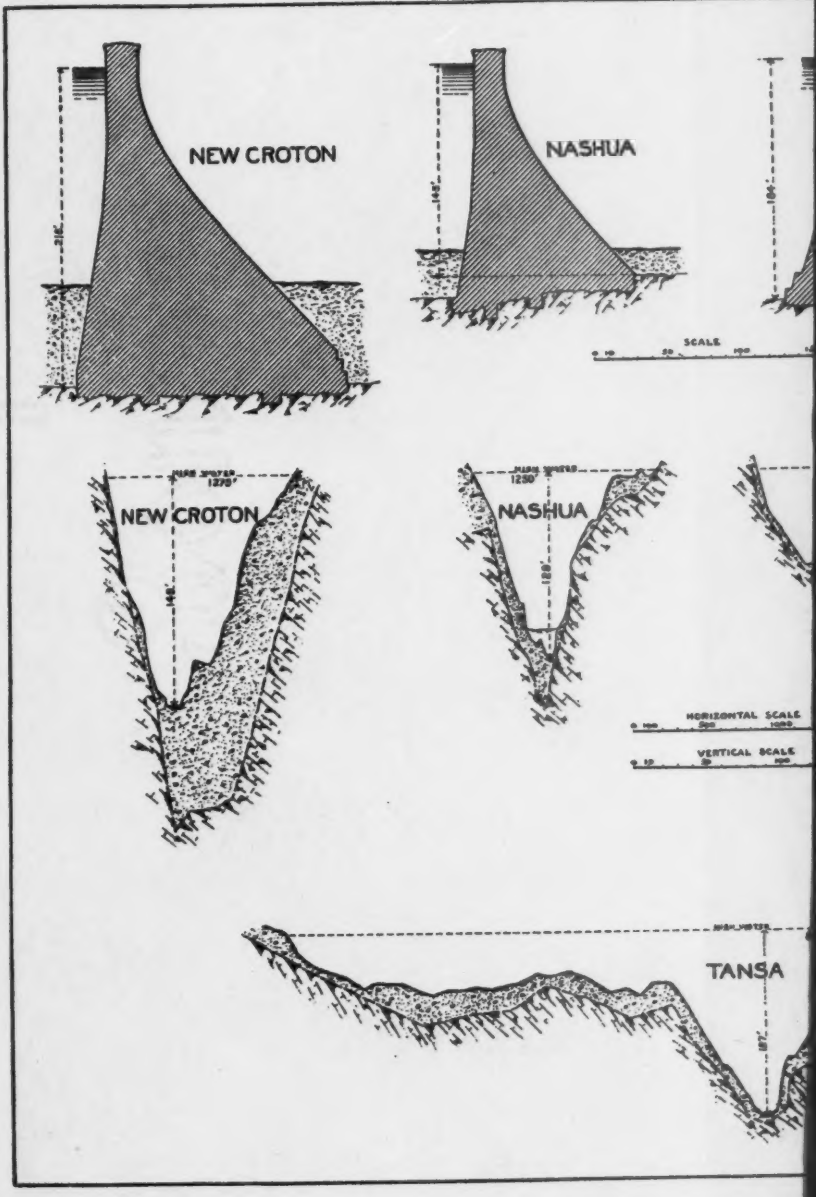
TABLE III.

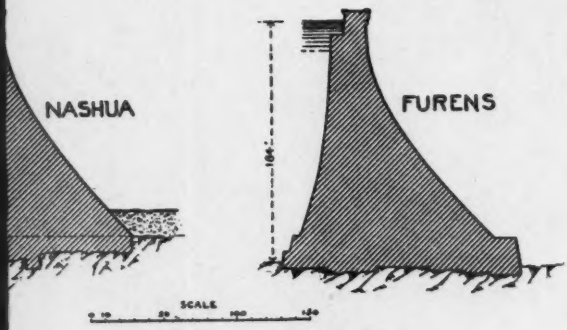
TABLE SHOWING THE AVERAGE HARDNESS AND COLORS OF WATERS AND THE POPULATION PER SQUARE MILE UPON CERTAIN WATERSHEDS.

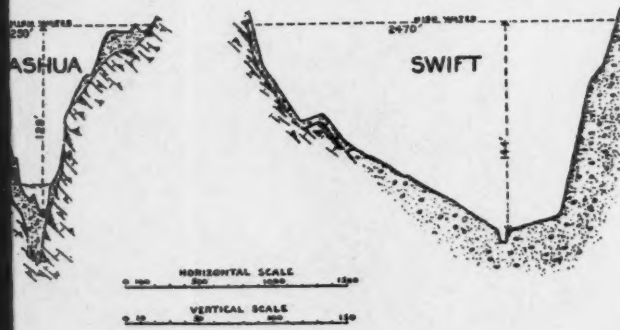
	Hardness.	Color.	Population per Square Mile. (1894.)
Deerfield River above Shelburne Falls	1.5	0.40	21
Swift River at Belchertown	0 8	0.38	30
Ware River at Cold Brook	0.7	0.75	32
Lake Winnipiseogee	1.3	0.01	35
Assawompsett Pond	0.6	0.28	36
Tributaries of Assabet River	1.6	0.36	60
Nashua River above Clinton	**1.1**	**0.40**	**69**
Ipswich River at Danvers	1.7	1.36	72
Stony Brook at Cambridge dam	2.1	0.71	107
Shawsheen River at Old Middlesex Canal crossing	1.8	0.89	123
Charles River above South Natick	1.4	0.86	179
Sudbury River	1.5	0.87	376–165
Lake Cochituate	2.0	0.22	770–185
Saugus River at Howletts dam	3.5	1.16	709
Upper Mystic Lake	5.2	0.11	984

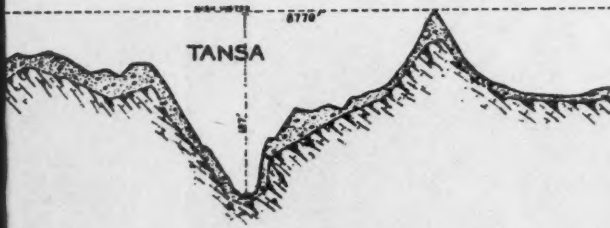
NOTE.—Where two figures are given for population per square mile, the first is the total population and the second is the population remaining after deducting the districts from which the sewage has already been or is soon to be diverted to a point outside the watershed.

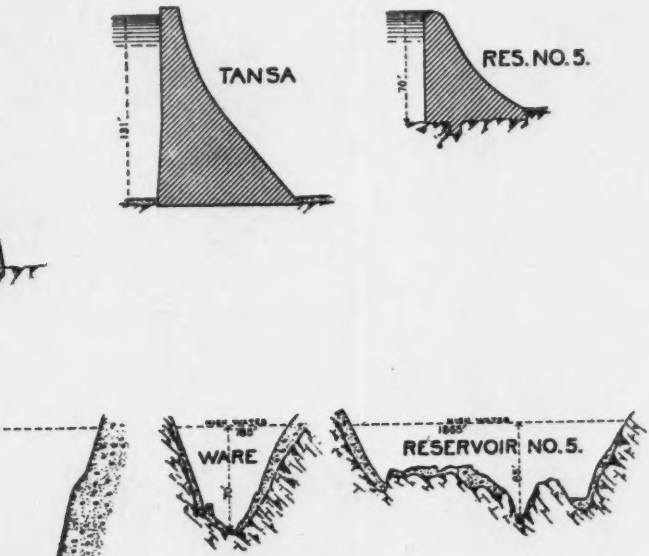
It will be seen that the Nashua river watershed has a population of 69 persons to the square mile, and the water from it has a color of 0.4 and a hardness of 1.1, and it will be seen that, as indicated by the color and hardness, it is an exceptionally good water. The complete analyses show that the water is in every way up to these


NEW CROTON
NASHUA
SCALE
NEW CROTON
NASHUA
HORIZONTAL SCALE
VERTICAL SCALE
TANSA


NASHUA
FURENS
SCALE

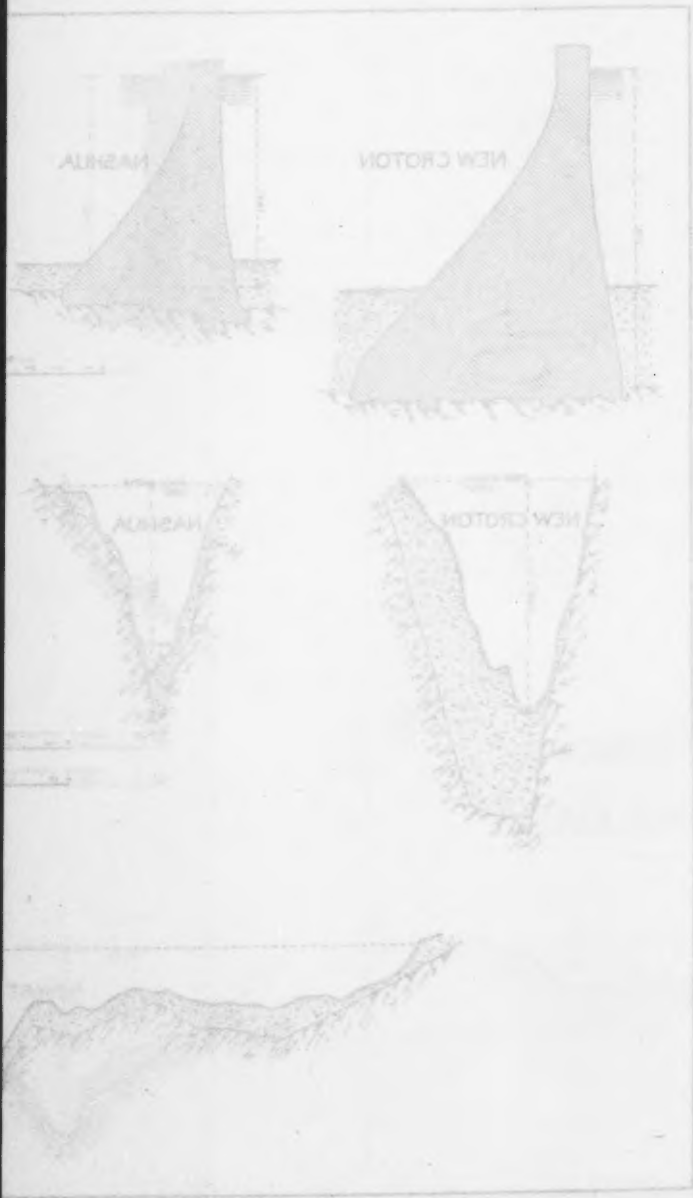

ASHUA
SWIFT
HORIZONTAL SCALE
VERTICAL SCALE


TANSA



COMPARATIVE SECTIONS
OF
MASONRY DAMS

HELIOTYPE PRINTING CO., BOSTON.


NASHUA
NEW CROTON
NASHUA
NEW CROTON

indications, and it is expected that with the long storage in the reservoir the color will be greatly reduced so that the water will be almost colorless, as is the water in Lake Winnipiseogee, which is so often mentioned as an exceptionally good water.

In Table IV. are given some statistics relating to the Nashua river watershed and reservoir. The destruction of town, railroad, and mill property will be unprecedented. The greater part of the small manufacturing village of West Boylston, and the whole of the smaller village of Boylston, will be flooded as will the lower parts of the village of Oakdale.

TABLE IV.

STATISTICS RELATING TO NASHUA RIVER WATERSHED.

Area of watershed, square miles	118.23
Population upon watershed	8,188
Villages with populations of over 100	10
Population of these villages	4,446
Farming and scattered population	3,742
Area of swamps, square miles	3.63
Area of existing ponds and reservoirs	2.19

STATISTICS RELATING TO NASHUA RIVER RESERVOIR.

Estimated cost	$9,105,000
Area of water surface, square miles	6.56
Capacity, gallons	63,068,000,000
Length, miles	8.41
Maximum width, miles	2.05
Shore line, excluding islands	35.4
Maximum depth, feet	129
Average depth, feet	46
Length of railroad flooded, miles	6.56
Length of road flooded, miles	19.21
Dwellings in flooded area	224
Inhabitants in flooded area	1,711
Mills within reservoir	6
Churches	4
School houses	6
Time required to fill reservoir, years (about)	1.5

Notwithstanding all of the costs for damages involved in destroying these manufacturing villages and the large cost of removing the soil and organic material to make a perfectly clean and sanitary basin, Table V. shows that the relative cost reduced to million gallons of water stored is quite low, less than in the various reservoirs which have been constructed in the vicinity of Boston. Thus the cost per million gallons in the Nashua river reservoir will be $144, as against $400 in Hobbs Brook reservoir, and $336 in reservoir No. 5.

TABLE V.

COST PER MILLION GALLONS OF WATER STORED.

City.	Name of Reservoir.	Acres Flowed.	Storage in Million Gallons.	Cost per Million Gallons.
Boston	Reservoir No. 1	143	280	$918
Boston	Reservoir No. 2	134	530	879
Boston	Reservoir No. 3	253	1,080	388
Boston	Reservoir No. 4	167	1,400	581
Boston	Reservoir No. 5	185	1,530	566
Boston	Reservoir No. 6	1,220	7,438	336*
Cambridge	Proposed reservoir on Hobbs Brook†	350	1,500	400
Greater Boston	Proposed reservoir on Nashua River	4,195	63,068	144

It is estimated that 1898 when, under favorable circumstances, the first supply of water can be obtained from the Nashua river, the consumption of water in the district will be about 100,000,000 gallons, and as the capacity of the present source in a dry year is only estimated at 83,000,000 gallons, it will be seen that the work of obtaining a new supply was begun none too soon.

It is proposed that the Metropolitan Water Board shall take charge of the distribution of water to the various cities and towns. At first the water will all be brought to Chestnut Hill reservoir. From this point a small part of it will be pumped by a low-lift pump to Spot Pond, which will act as a distributing reservoir for the northern part of the district. It is now used as a source of supply for the town of Melrose and the cities of Malden and Medford jointly. A high service station will be located near Spot Pond for pumping to the higher portions of the northern part of the district. As mentioned above, when the capacity of the aqueducts leading to Chestnut Hill reservoir is reached, an additional aqueduct will be built leading directly to Spot Pond.

The strongest evidence of the care and judgment used in perfecting the plans is furnished by the fact that not a word of criticism of any engineering feature of the plans has been advanced by any engineer or superintendent of the various municipalities in the

*Based upon estimated cost of reservoir.

†The figures for this reservoir are based upon preliminary estimates of cost and capacity, as given in the annual report of the Cambridge Water Board for 1893.

CROSS SECTIONS
OF THE PROPOSED
NASHUA-SUDBURY AQUEDUCT

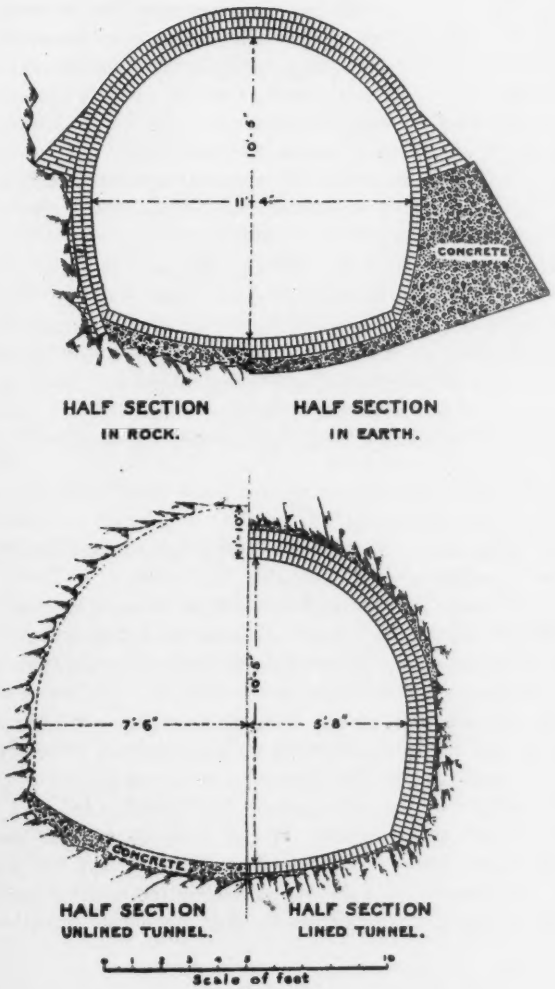


FIG. 4.

district. It has commended itself to all, as being not only a plan which will meet all the requirements, but as having been so carefully considered there is every reason to believe that it is the best one, and the cities that have objected to being included in the Metropolitan district have based their objections upon the cost of the work and the fact that they believed their present supplies were sufficient for their immediate needs, and they were unwilling to meet at the present time the expense of providing water for themselves at a much later date. It is also very gratifying to the originators of the project that the General Court has met the question squarely, and has created a water board to carry out the project, and one of our members, Mr. John R. Freeman, has been given a place upon the board with Mr. Stearns as chief engineer, and Mr. Brackett, until today our senior editor, as engineer in charge of the Department of Distribution.

A word should be said in acknowledgement of credit which is due to the members of the Massachusetts State Board of Health for their consideration of the questions. While Mr. Stearns has had charge of them, he has always had the support and wise advice of the members of that board, and I can assure you from my close acquaintance with them and with the details of their work, that their advice has gone a long way towards the successful carrying out of this plan.

DISCUSSION.

THE PRESIDENT. Mr. Noyes would be glad to answer any question any member would like to ask.

Mr. CAIRNS. I wish Mr. Noyes would tell us in a word or two how the cost of this work is to be distributed and borne.

MR. NOYES. The work is paid for by the proceeds from the sale of bonds of which $27,000,000 are authorized. The bonds are payable in not less than 30 nor more than 40 years, and the interest on them and the contributions to the sinking fund necessary to pay them at maturity and the operating expenses for each year are added together by the treasurer and distributed as follows:

Boston pays that proportion of the whole amount that the valuation of Boston bears to the valuation of all the property in the district. The remainder is distributed among the remaining cities and towns, one-third in proportion to their respective valuations, and

two-thirds in proportion to their respective populations, but with this exception, that the cities and towns in the Metropolitan district which have not yet reached the safe capacity of their works in a dry year and have not applied for or received water from the Metropolitan Water Board, pay only one-sixth as much proportionately as the other cities and towns, that is to say, until they need the water, for the purpose of this calculation, their populations and valuations are taken at only one-sixth of the actual, while the other cities and towns are reckoned upon their full populations and valuations.

MR. CAIRNS. What becomes of the present sources?

MR. NOYES. The present sources will be utilized so far as that can be done, but many of them ought to be abandoned at the present time, and would be if other sources were available. Boston's principal sources are to be taken by the Metropolitan Water Board for the benefit of the whole district. It will be found gradually that the other sources cannot be maintained, either from sanitary reasons or from an economical standpoint, and they will gradually be abandoned. But for the most part they are very insignificant, and although they have, up to the present time, fairly well supplied the district, yet the district is fast outgrowing them.

MR. CAIRNS. Are any of these places supplied by private companies.

MR. NOYES. Yes; some four or five of them are at the present time so supplied. One of the companies has signified its perfect willingness to give the town a bond to pay all of the cost that would be assessed on the town for a supply. The other municipalities are taking steps towards purchasing the works, so it is anticipated that, with possibly one or two exceptions, there will be no supply in the Metropolitan district operated by a private company.

STATISTICS

FOR

The Year 1894.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

TABLE I. —GENERAL AND PUMPING.

TABLE II. —FINANCIAL.

TABLE III.—CONSUMPTION.

TABLE IV.—DISTRIBUTION—MAIN PIPE.

TABLE V. —DISTRIBUTION—SERVICE PIPE.

Compiled by the
JUNIOR EDITOR,
New London, Conn.

TABLE I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Kind of Fuel.	Per Cent. Ashes.	Price Per 2,240 lbs.
1	Attleboro, Mass...	1873	Well	Pump to S. P.	Blake and Deane	Bituminous		$ 4.60
2	Bay City, Mich...	1872	Lake Huron	Pump Direct	Holly	Coal and Pine		
3	Boston, (Cochitu'e)	1848	Lake Cochituate and Sudbury River	Gravity and Pump to Reservoir	Holly and Quintard	Bituminous	7.4	4.40 to 4.52
4	Boston, (Mystic)..	1864	Mystic Lake	Pump to Reservoir	Worthington	Bituminous	11.2	3.75 to 5.25
5	Brockton, Mass...	1880	Reservoir	Pump to Stand P.	Worthington	Bit. and Anth.	9.7	4.76 to 6.45
6	Burlington, Vt....	1868	Lake Champlain	Pump to Reservoir	Worthington	Anth and Shav		5.09 to 5.95 & 38.50 per wk.
7	Fall River, Mass..	1874	Watuppa Lake	Pump to Stand P.	Worthington and Davidson	Bituminous		
8	Fitchburg, Mass...	1872	Storage Reservoir	Gravity				
9	Lynn, Mass.....	1872	Storage Reservoir	Pump to Reservoir	Leavitt and Loretz	Bituminous		3.65 to 4.50
10	New Bedford, Mass	1869	Storage Reservoir	Pump to Reservoir	McAlpine, Worthington and Worthington H. D.	Bit. and Anth.	8.0 12.0 16.0	4.20 to 5.00
11	New London, Conn	1872	Lake Konomoc	Gravity				
12	Newton, Mass.....	1876	Filter basin and wells	Pump to Reservoir	Blake and Worthington	Bituminous	6.0	4.13
13	Oberlin, Ohio....	1887	Vermillion River	Pump to Stand P.	Deane	Bituminous		2.35 to 2.50
14	Plymouth, Mass...	1855	Ponds	Gravity and Pump.	Worthington	Bituminous		4.25
15	Springfield, Mass..	1864	Storage Reservoir	Gravity				
16	Taunton, Mass....	1876	Elders Pond	Pump Direct	Holly and Allis	Bituminous	8.28 .42	3.85 4.20
17	Waltham, Mass...	1873	Filter Basin	Pump to Reservoir	Worthington	Cumberland	15.0	4.87 to 5.75
18	Woonsocket, R. I..	1884	Crookfall Brook	Pump to Tank	Worthingt'n and Deane	Bituminous	7.6	4.35
19	Yonkers, N. Y.....	1876	Storage Reservoir	Pump to Reservoir and S. P.	Wright and Worthington	Anthracite	12.8	5.09

TABLE I.—GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, lbs.	4. Lbs. of Wood. / 3.	5. Total Fuel for Year, lbs.	6. Total Pumpage for Year. Gallons.	7. Average Static Head on Pumps.	8. Average Dynamic Head on Pumps.	9. Gallons Pumped per lb. of Coal.	10. Foot lbs. per 100 lbs. of Coal, no Deductions.	11. Cost per Mil. Gals. Pum'd. Pump'g Station Expen.	12. Cost per Mil. Gals. 1 foot High. Pump'g Station Expen.	13. Cost per Mil. Gals. Pumped. Total Mainte'e.	14. Cost per Mil. Gals. 1 ft. High. Total Mainte'e.
1	451,050	1,000	452,050	99,136,440	160.0	175.0 / 188.0	219.8	34,385,136	$ 18.76	$ .10	$ 145.87	$ .775
2				1,024,735,621		113.0			7.29	.064	44.39	.393
3	4,637,660			3,795,830,595		126.1	818.6	86,459,300	6.62	.052		
4	8,763,800			3,751,418,700		148.6	428.1	53,057,500	8.77	.059		
5	494,707	225	494,932	314,854,473		43.0	636.0	22,813,863	8.59	.199	99.11	2.30
6				336,504,725	289.0	316.0			23.59	.074	128.04	.405
7	2,994,880			889,954,187		185.8	297.1		12.56		148.44	
8												
9	454,400	200	454,600	363,138,230		160.5	798.8	106,966,048	6.29	3.93	84.86	.529
	1,426,800	900	1,427,700	1,105,150,200		159.8	774 7	103,176,674				
10	1,000,995	33	1,001,028	649,615,574	125 8	135 1	649.0	73,097,580	6.74	5.18	30.66	.235
	305,800	133	305,933	157,965,580	125.8	127.0	516.0	54,694,053				
	1,225,600	540	1,225,780	959,810,926	125.2	127 5	783.0	83,295,142				
11												
12	1,585,100	10,000	1,595,071	597,591,100	234 0	260 0	374.0	82,536,000	12.70	.049	170.67	.66
13	237,780			25,234,000	70 0	70.0	107.0	6,220,000	45.71	.653	156.56	2.23
14	248,880		248,880	109,248,480	65.0	66.0	448.2	24,670,170	14.26	.216	90.98	1.38
15												
16	771,800			400,836,270		108.09	519.8	46,818,102	11.62	.107	140.29	1.39
	224,350											
17	1,728,700			452,227,087	164.0	190.0	260.0	41,603,620	19.90	.105	113.48	.60
18	784,159	103	784,262	206,765,840	239 0	240.0	262.0	52,996,254	16.65	.069	132 58	.55
19	25,196		25,196	5,959,553	185.0	196.0	236.0	38,663,771	12.54	.057	98.67	.448
	3,600,913	8,933	3,601,846	986,053,346	185 0	220.0	274.0	50,230,095				

TABLE II.—FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
1	Attleborough, Mass	$	$	$ 11,174.60	$	$
2	Bay City, Mich.			22,820.83		
5	Brockton, Mass			41,653.56	191.64	41,845.20
6	Burlington, Vt.	33,249.10	4,975.74	38,224.84		
7	Fall River, Mass.			111,419.57		
8	Fitchburg, Mass	47,229.71	9,402.97	56,632.68		
9	Lynn, Mass.	134.306.91	37,143.25	171.450.16	1,781.57	173,231.73
10	New Bedford, Mass.	76,677.46	6,838.73	83,516 19	162.85	83,679.04
11	New London, Conn.			38,634.05		
12	Newton, Mass.	71,170.65	6,800.00	77,970 65	4,332.50	82,303.21
13	Oberlin, Ohio.	2,858 00	320.15	3,178.50		
14	Plymouth, Mass	16,373.89	1,568.64	17,942.53	451.78	18,594.31
15	Springfield, Mass			158,461.46	24,430.29	182,891.75
16	Taunton, Mass.	37,257.38	10,068.28	47,325.66	795.18	48,120.84
17	Waltham, Mass.	48,679.75	5,110.65	53,790.40	14,073.52	
18	Woonsocket, R. I.	25,318.75	6,342.25	31,661.00	101.11	31.762.11
19	Yonkers, N. Y	70,959.37	25,754.67	96,714.04	2,249.58	98,963.62

TABLE II.—FINANCIAL—Continued.

Number.	Receipts from Public Funds.					K	AA.	BB.	Miscellaneous Expenses.	Total Maintenance.
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.		
1	$	$	$	$	$ 6,800.60	$ 47,981.50	$ 5,191.38	$ 9,270.00	$	$ 14,461.38
2										16,977.98
5	3,000.00					44,845.20	7,581.38	23,625.66		31,207.04
6	2,960.00			370.00		43,067.99	31,867.12	8,760.00	625.00	41,252.12
7					20,000.00	137,532.39	43,171 81	99,835.00		143,006.81
8							23,287 96			36,987.16
9					50,198.13		47,449.30	77,158.62		124,607.92
10					29,866.67	113,545.71	31,491.02	37,866.67		69,357.69
11						52,509.05	6,709.22	24,540.00		31,249.22
12	14,000.00	1,195.31	2,400.00	1,022.83	890.77	101,812.12	15,995.99	86,000.00	3,771.22	105,767.21
13					2,485.00	5,663.15	1,556.38	2,410.00		3,966.38
14						18,594.31	5,075.59	4,864.00		9,939.59
15	14,340.00	1,802.00	4,308.25	3,883.50	25,000.00	233,105.50	19,437.33	99,500.00	7,358.34	126,295.67
16	3,500.00	1,915.06	800.00	551.93		62,887.83	17,470.53	38,816.50		56,287.03
17	1,482.99			705.50			35,349.55	15,980.00		51,329.55
18	13,832.00	1,110.40	1,639.25	747.07	9,639.58	58,730.41	9,692.46	17,722.04		27,414.50
19	14,390.00					114,653.62	30,934.56	69,283.33		100,217.89

TABLE III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.			Quantity used through Domestic Meters—Gals.	Quantity used through Man'f'tring Meters—Gals.		Average Daily Consumption Gallons.	Gallons Per Day.		
		Total at Date.	On Line of Pipe.	Supplied at Date.					Each Inhabitant.	Each Consumer.	Each Tap.
1	Attleborough, Mass.	8,000	6,500	5,000				271,606	34.0	54.0	
2	Bay City, Mich.....	33,000	19,500	13,500	52,255,126	52,888,770		2,807,495	83 0	208.0	1,528.0
3	Boston (Coch).....	466,500		460,000	4,077,196,000		24.	46,560,000	99.8	101.2	679.2
4	" (Mystic).....	117,400		116,000	735,110,000		19.6	10,282,100	87.6	88.6	442.1
5	Brockton, Mass.....	31,000	27,280	24,800	78,894,500	28,404,750		862,615	27.8	34.7	222.6
6	Burlington, Vt.....	15,700	15,700	15,100	63,535,928	30,319,072		921,930	60.0	61.0	325.0
7	Fall River, Mass....	89,576		85,576				2,438,231	27.2	28.4	
8	Fitchburg, Mass ..	28,500	25,200	22,300	56,571,000	168,000,000		2,225.000	78.0	90.0	602 0
9	Lynn, Mass. ...	69,400		66,930	195,716,250			4,020,344		60.0	
10	New Bedford, Mass..	56,000	45,512	44,661	13,590,386	233,494,702		4,786,760	85.0	107.0	616.0
11	New London, Conn.	15,000	14.700	14,000				1,244,320	83.0	89.0	467.0
12	Newton, Mass	29,300	28,900	28,500	215,000.000	89,000,000		1,622,605	55.4	57.0	290.0
13	Oberlin, Ohio	4,500	3,600	1,850	4,197,000	1,123,000	21.	69,000	15.3	37.0	174.7
15	Springfield, Mass...	51,851	45,000	38.500	280.259,913			4,524,510	87.0	117.0	604.0
16	Taunton, Mass ..	25,448	23,600	23,545	53,106,757	101,417,264		1,099,103	43.0	46.7	293 0
17	Waltham, Mass.....	22,000	21,000	20,000	25,208,860			1,238,975	56.3	59.0	414.0
18	Woonsocket, R. I...	25,000	23,000	20,000				563,368	22.5	26.1	325.0
19	Yonkers, N. Y	36,000	32.000	31,000	242,240,862	346,630,680	61.5	2,623,760	73.0	85.0	800.0

TABLE IV.—DISTRIBUTION—MAIN PIPES.

Number.	Name of City or Town.	1. Kind of Pipe Used.	2. Size of Pipe, Inches.	3. Length Extended During Year, Feet.	4. Length Discontinued During Year, Feet.	5. Total Length in Use, Miles.	6. Cost of Repairs Per Mile.	7. Number of Leaks Per Mile.	8. Length of Pipe Less Than 4 in., Miles.	9. Hydrants. No. Added.	10. Hydrants. Total in Use.	11. Stop Cocks. No. Added.	12. Stop Cocks. Total in Use.	15. Range of Pressure, Lbs.
1	Attleborough, Mass	C. I. & C. L	4 to 16	20,751		28.3	$	0.15		51	221			50 to 62
2	Bay City, Mich...	C. I. & Wyckoff	3 to 20	2,258	171	43.	15.59	1.	.6	4	370	7	647	35 to 38
3	Boston, (Coch)	C. I.	4 to 48	67.320		572.8			1.7	175	6,217	193	6,359	
4	Boston, (Mystic)..	C. I., W. I. & C. L.	3 to 30	36,432		173.7			4.7	148	1,446	156	2,138	
5	Brockton, Mass ..	C. I., W. I. & C. L.	6 to 30	28,340	6,160	50.	1.74	0.3		32	453	82	467	47 to 56
6	Burlington, Vt ..	C. I., W. I. & C. L.	4 to 24	8,580	7,352	34.9	18.31	1.	2.7	12	187	65	448	70 to 85
7	Fall River, Mass..	C. I.	6 to 24			74.				41	743	34	748	80
8	Fitchburg, Mass...	C. I., W. I. & C. L.	2 to 30	9,722		57.3	7.87		1.5	21	388	21	429	75 to 80
9	Lynn, Mass.....	C. I. & C. L.	2 to 20	4,006		121.6				10	783	6	320	50 to 65
10	N. Bedford, Mass.	C. I. & C. L.	4 to 30	17,290	4,522	74.6	22.16	10.	1.2	22	607	27	835	29 to 40
11	N. London, Conn.	C. I. & C. L.	4 to 20	7,858		43 1	10.60	7.	2.9	5	198	8	227	45 to 50
12	Newton, Mass.....	C. I.	4 to 20	22,021		113.5	11.75	.09	2.7	24	760	38	602	84
13	Oberlin, O	C. I.	4 to 12	2,200		7.5	1.22	.13	.3	5	70	2	44	27 to 32
14	Plymouth, Mass..	W. I. & C. L.	2 to 20	1,625		33.4	7.30	1.	9.5	2	105	10	307	
15	Springfield, Mass..	W. I., C. L. & C. I.	¾ to 36	80,529	5,357	117.2	6 07	.31	41.2	28	717	99	1,307	30 to 35
16	Taunton, Mass....	C. I.	4 to 20	7,550		70.5	30.65	9.	1.1	23	681	14	466	45 to 50
17	Waltham, Mass....	C. I., W. I. & C. L.	2 to 24	5.577		47 1	11.32	.8		12	262	41	585	55
18	Woonsocket, R. I..	C. I.	4 to 20	13.992	1,103	40.2	3.38	.65	0	25	457	18	387	90 to 115
19	Yonkers, N. Y. ..	C. I.	4 to 30	12,076		49.8	12.59	1.	0	10	523	21	329	

TABLE V.—DISTRIBUTION—SERVICE PIPES.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind of Pipe Used.	Size of Pipe. Inches.	Length Extended. Feet.	Length Discontinued. Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number Added.	Now in Use. Domestic.	Now in Use. Manufac'ing.	No. Added.	Total in Use.
1	Attleborough, Mass									$	83	599		1	1
2	Bay City, Mich....	Lead, W. I. and Wood.	½ to 8				44	1,837			57	516			
3	Boston, (Coch)....	Lead.	½ to 6	49,841			1,970	68,556			291	4,337			540
4	" (Mystic)...	Lead and W. I.	½ to 4	18,436			859	23,257			33	494			21
5	Brockton, Mass...	C. I., W. I. and C. L.	1 to 6	4,849	71	17 6	224	3,874	22.1	9 37	241	2,478			
6	Burlington, Vt .	Lead and Gal. I.	½ to 6	2,794	56	15.3	98	2,835	28	10.00	206	1,008	75	9	26
7	Fall River, Mass..	Lead.	½ to 2				345	6,138			359	4,887			
8	Fitchburg, Mass..	W. I., C. L. and C. I.	½ to 8	8,186		41.5	162	3,736	58	14.06	151	1,432	115	4	55
9	Lynn, Mass.....	W. I., C. L. and Gal.	½ to 10	16,305	3,140	87.0	318	10,827			221	890			
10	New Bedford Mass	Lead and C I.	½ to 8	8,673	563	48.1	236	7,767	33	8.93	49	163	59	37	68
11	New London, Ct..	Lead, Gal. C. L. & C. I.	½ to 4	2,408		9.7	108	2 663	22 3	10.85	9	167			22
12	Newton, Mass.....	Lead, W. I. and C. I.	½ to 6	16,046		64.1	305	5,586	60.9	13.59	456	4,224	23		16
13	Oberlin. Ohio. ..	Gal. and Lead.					72	399	25	8.00	31	97	5	0	0
14	Plymouth, Mass...	Lead and C. L.	½ to 1	315		5.5	37	1,578	18.5	4.28					1
15	Springfield. Mass..	W. I., Tar, Gal. & C. I.	½ to 6				482	7.482			269	1,947		2	144
16	Taunton, Mass ...	C. L.	½ to 3	5,438	5,108	36.2	124	3.751		11.68	80	1,176	134		13
17	Waltham, Mass...	C. I. and C. L.	½ to 6	4,560	974	33.2	52	2,990	81	25.37		75			11
18	Woonsocket, R. I..	Lead and Iron.	½ to 6	1.667			110	1,667	15.1	12.24	87	1,386	41	1	6
19	Yonkers, N. Y....	Lead and C. I.	½ to 8				213	3,504			234	3,371	111		8

OBITUARY.

HORACE L. EATON.—City Engineer of Somerville, Mass. Died November 23d, 1895. Joined this Association February 13th, 1889.

Mr. Eaton was a native of Boston, and was educated in the Boston public schools, and for many years was employed by the city in connection with the City Engineer's office. From 1870 to 1872 he was employed upon the high service water supply of Roxbury; upon surveys for water supply for Deer Island; upon the construction of the Chestnut Hill Reservoir for the Boston Water Works; the Atlantic Avenue sea wall; high service water supply for South Boston and Dorchester, and other works. In 1873 he was employed upon the construction of the Parker Hill Reservoir. In 1874 he was in charge of field work in connection with the Malden bridge, and in 1875 to 1876 he was in charge of preliminary surveys for the Mystic Valley sewer and on plans for bridges on Massachusetts avenue and Central street. In 1877 and 1878 he was employed upon the construction of the Mystic Valley sewer. From 1884 to 1887 he was engineer in the work of developing the Arnold Aboretum and Franklin and Wood Island Parks, and other similar work. In 1887 he was appointed City Engineer of Somerville, which position he has held up to the date of his death. He was a member of the American Society of Civil Engineers, and of the Boston Society of Civil Engineers, and was secretary of the latter for five years following 1882.

During November, 1895, an investigation of his department was commenced by the City Council, and although the investigation had hardly commenced, and nothing of importance derogatory to the conduct of his office had been developed, the fact that his integrity had been questioned preyed upon his mind and led to the cause of his death.

Mr. Eaton was noted for the thoroughness of his work, and was respected by a large circle of associates.

CORNELIUS F. DOHERTY.—Boston, Mass. Died November 17th, 1895. Joined this Association February 16th, 1894.

Mr. Doherty was employed in the service department of the Boston Water Works from 1883 to 1892, and was Water Registrar of the City of Boston from 1892 to July 1st, 1895.

FRED. I. CHAFFEE.—Superintendent of the East Providence Water Company, East Providence Centre, R. I. Died November 28th, 1895, aged 40 years. Joined this Association December 14th, 1892.

Mr. Chaffee was Superintendent of the East Providence Fire District, and the plant now owned by the Water Company was built under his direction. He has occupied many positions of responsibility, among which was postmaster and State constable.

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